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HOISTING THE ANTENNA

Experimental wireless Telegraphy and Telephony (See page 12)

How to Study Steel*

The Solid and Liquid States of Steel, and Need for Carefully Studying Each

By Cosmo Johns, F.C.S., F.G.S., M.I. Mech. E.

There are only three states known in which matter can exist—namely, the solid, liquid, and gaseous. It is true that references abound in scientific and technical literature to a supposed "amorphous" state, but evidence has accumulated which makes it clear that this is not a state distinct from the three already mentioned, but is always a modification of either the solid or liquid forms, or possibly a mixture of both. It is the object of this communication to make clear so far as possible the difference between the solid and liquid states in the case of steel, and to point out the necessity for observing such distinctions if progress is to be made in the scientific study of that most important constructional material. It will only serve still further to emphasize the need for further study and still more careful observations if the illustrations are selected from everyday occurrences in any and every steel works. Only rare allusions have been made in the literature of steel to the gaseous phase of that metal, though there is abundance of evidence that molten iron has an appreciable vapor pressure at the temperature employed in the open-hearth melting furnace. The vapor of iron as it rises is rapidly oxidized by the furnace gases to magnetic iron oxide, the only stable form at high temperatures, and not only permeates the refractories which line the furnace, but also falls as a mist of rain of minute globules of molten oxide on the surface of the slag present, thus profoundly affecting the direction of the reactions that take place. A clean silica rod or other object would be coated, in the course of half an hour, with a film of oxide 5 mm. thick. Interesting and important though the vapor phase may be, its discussion at any length is outside the scope of the present lecture, and the subject will only be referred to incidentally when describing the surface phenomena of liquid steel.

It will assist in avoiding ambiguity of expression, and thus tend to clearness of thinking, if we define with some approach to exactness the substance we are dealing with and the particular states of that substance which we purpose discussing. Many attempts have been made to define "steel," but with very limited success, for each attempt was followed by demonstrations that striking exceptions existed. It is now proposed to define steel as "iron to which appreciable quantities of some element, or elements, have been added during manufacture for the specific purpose of modifying, or adding to, its desirable properties." It will be interesting to note whether this definition will escape the fate of previous attempts in the same direction. It will be useful to mention that in the present paper the accepted definition of a solid, that it is a "crystalline aggregate," will be employed. Now, as a crystal is a body whose atoms are oriented according to a definite system, the accepted definition of the change from the solid to the liquid state can be stated as follows: When by the application of heat, with or without a change of pressure, the atoms of the crystals composing the solid substance cease to be oriented, that particular substance no longer exists as a solid, and has acquired new and distinctive properties. It may still possess considerable rigidity; it may be unable to flow under the influence of gravity; it may still retain the outward appearance of solidity, but it has suffered a profound alteration, and exists in a new state, the recognition of which is important. This is the glassy or vitreous modification of the liquid state to which the term "amorphous" is often applied. It is much better to speak of it as vitreous in the sense used by Beilby, who has contributed so much to our knowledge of this modification of the liquid state of metals. Strictly speaking, it is an undercooled liquid with the rigidity of a sold, but in other respects possessing the properties of a liquid. It might be disturbing to have to consider ordinary glass as an undercooled liquid, but to define it as a solid substance would create more difficulties than would be avoided. When the substance can flow under the influence of gravity, as most liquids do, there is no difficulty in accepting the definition of the liquid state.

THE SURFACE OF LIQUID STEEL.

If a stream of acid steel be observed as it flows from the launder of an open-hearth furnace into the ladle, or from the lip of a crucible as it is poured into a mould, and if care be taken to select that portion which is free from oxide films or slag, it can be seen under suitable conditions that the surface of the pure metal has very definite properties. Many must have observed a difference in the intensity of the heat radiated when the first flush of slag comes as the flow of steel decreases. The heat radiated is much greater, though it is certain that the slag and steel so closely following each other must be at the same real temperature. From this we learn that liquid acid open-hearth slag and steel of the same real temperature radiate differently, and that the heat emitted by different bodies in the open air does not indicate their true temperatures. When the conditions are suitable the stream of steel can be seen to reflect the sunlight as brilliantly as many mirrors, and the light from an electric arc light is also reflected when suitably placed. No such reflection takes place from a surface of liquid slag, and thus liquid slag and liquid steel are illustrations of the truth that good reflectors are bad radiators even when they are in the same—in this case both liquid—state. But if we follow our liquid steel until it has been poured into a mold, and the free radiating exposed surface observed, it will be found that at the moment of solidification there is a marked rise in the intensity of the heat radiated. This can be better observed with copper, which is usually cast into open molds, and allowed to freeze or solidify with its upper surface exposed to the atmosphere. Here the increase in the intensity of the heat radiated is very marked, and is sufficient to cause a change from comfort to extreme discomfort on the part of an observer standing near if a large surface is exposed. We thus learn that not only do different substances at the same true temperature emit heat varying in intensity, but that the same metal will radiate heat with more intensity when it has just solidified than it did when in the liquid state. This phenomenon has been explained as due to a real rise in temperature as the metallic mass passes from the liquid to the solid state, but though this actual rise in temperature might occur under certain circumstances owing to undercooling, it falls very far short of explaining the great rise in the intensity of the heat radiated in the cases mentioned. That some other cause must be sought will become clear when we observe an ingot of steel at a temperature much below its melting-point passing through the rolls of a cogging mill. During the early passes the coating of scale falls off and the intensity of the light or heat radiated can be measured by suitable pyrometers. It is found that the newly-exposed surface of the steel radiates almost as a black body. Its emissivity is 0.97, which is near enough to unity for the readings of an optical pyrometer to be taken as true temperatures. The surface of solid steel is therefore an exceptionally good radiator. It is not without significance that no reflection of sun rays or electric lights can be observed from the freshly exposed surface of a steel ingot even immediately after its coating of scale has fallen off.

Before discussing further these differences, however, it will serve some useful purpose if we consider further the nature of the surfaces we have been observing, and thus be certain whether we are or are not observing the pure metallic surface. Now, the higher the temperature, the more rapid the oxidation of steel, so we should expect the greatest difficulty to occur when observing a stream of liquid steel. Careful observation with an optical pyrometer, and even, sometimes, with ordinary blue glass, reveals the occasional presence of brighter-looking patches of oxide film on the surface of the swiftly-flowing steel, but these are chiefly on the upper turbulent surface. If the side of the stream be observed as it leaves the launder it can be seen to be an optically clean metallic surface. This oxide-free surface is preserved for a considerable distance down the stream, and the question arises as to how this pure metallic surface of liquid steel is preserved from oxidation during its exposure to the oxygen of the atmosphere. It is to the existence of a vapor phase that this must be attributed. The constantly renewed layer of iron vapor suffers oxidation itself in its outer layers, but its presence serves to preserve the surface of the liquid steel from contamination with oxide. In the case of the steel solidifying in an open mold, this evolution of vapor ceases when the metal becomes solid, and the surface oxidizes instantly. It is the high emissivity of iron oxide that explains the greater intensity of the heat radiated when liquid steel passes into the solid state. The ingot of steel at the usual rolling temperature, whose freshly exposed surface was found to possess such a high degree of emissivity, was coated with a layer of newly-formed oxide. Solid steel possesses no effective vapor pressure; its metallic surface at rolling temperatures is instantly oxidized and it is the oxide and not the metallic surface that we were observing. If, however, we take a plane surface of solid steel and polish it carefully, we do get a fairly effective mirror which will reflect light, and does not act as a good radiator of heat. But Beilby has shown by his experiments on polished surfaces of metals that the polishing has caused a profound change in the polished surface—a change that can only be explained by the assumption that the extremely thin surface layer has been actually fused, and has flown over and filled the surface depressions, and that this thin fused surface layer, owing to its rapid cooling, due to the cold metallic mass which underlies it, has not had time to crystallize, and is therefore not truly in the solid state. It is in the vitreous or undercooled liquid form, very rigid, it is true, and hard too, but nevertheless possessing the properties of a liquid. It behaves when reflecting light just as the optically clean surface of liquid steel does.

THE SURFACE TENSION OF LIQUID STEEL.

The term "surface tension" has been used to describe those forces acting on the surfaces of liquids which act as if it were an elastic membrane. The action of these forces can easily be observed by pouring mercury on some plane surface of a material it does not wet. The globules can be made to roll about, and though in form they are not perfect spheres, they retain considerable rotundity, and obviously resist the effect of gravity. If two globules touch each other they coalesce to form one larger one, and an appreciable amount of force must be used to break the large globules into smaller ones. It is to this energy, acting on the surface of liquids, tending to alter their form to that offering the smallest possible surface, that the term surface energy has been applied. This surface energy or surface tension can be measured by appropriate means, and the values obtained vary for different liquids. These values are constants for the same liquid under similar conditions, but they would vary if the purity or other conditions of the experiment varied. Now, liquid steel has a surface-tension value comparable with that of mercury, but the determination of that value involves greater experimental difficulties than is the case with a metal that is liquid at room temperature. But though quantitative values are not easy to obtain, it is not difficult to demonstrate the existence of surface energy qualitatively. The small samples of liquid steel with a protective coating of slag which are withdrawn from steel-melting furnaces for testing purposes offer opportunities for observing surface-tension effects. They are best seen with acid steel where the conditions are favorable for establishing equilibrium between the steel and slag, and where the progress made towards the equilibrium can be conveniently followed. It is true that the sample can only be explained after solidification has taken place, but, as the solid sample retains the form it possessed in the liquid state, this introduces no difficulty, while there are considerable advantages. It should be made clear that high or low values for the surface tension of liquid steel are no criterion of the usefulness of the steel. For some purpose a steel with a high value is desirable, but for another class of product it would be most undesirable, and low values are, in practice, aimed for. The purpose of this discussion is not to indicate the type of steel most suitable for certain products—that has been decided in practice many years ago—but to describe observations that have been made, and to offer a reasoned explanation. It often happens in the relations of science and industry that some scientific truth has been discovered, and that many years have elapsed before it was applied to explain observations made by practical men in the course of industrial operations. Experienced melters have for years referred to the "skin" of the samples they take. They know that under certain conditions marked skin effects can be observed. That liquid steel behaves as if it had a skin is only to show that it behaves in the same way as mercury. To call the energy which has this effect on liquids "surface tension" is but a further step in

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knowledge, but it does possess the advantage that this knowledge is now exact; it is no longer empirical, and the way for further advances is made more clear. The literature of the metallurgy of steel contains few, if any, references to its surface tension, yet the workmen had not overlooked the phenomena, and knowing nothing of the advances made in pure science, had succeeded in giving a name to what they observed, which would have appealed to the worker in pure science as illuminating and suggestive, but which seems to have failed to arouse the interest of the earnest, but not always well-instructed, prophets of the new metallurgy, who think that they best serve the interests of industry by ignoring the progress of pure science and confining their attention to "applied" science, which too often is not science at all.

The appearance of the upper surface of the samples referred to above, changes in a marked manner as deoxidation proceeds. At first they are flat or distended with gases liberated at the moment of freezing, but as deoxidation proceeds the skin effect asserts itself, gases are no longer liberated, and the edges of the sample become rounded and the upper surface smooth. While it was flat dendrites were visible on the surface, and even when the greater portion of the upper surface of the sample has become smooth and rounded there will still remain a small depression to which the slag closely adheres, but which, if exposed, exhibits dendritic markings, indicating that the surface energy has not yet reached its maximum value. A later stage may be reached when the sample is fully rounded; dendrites are absent from its surface, and its contours are similar to an equal mass of mercury in the same mold. The surface is not only smooth, but, if the slag conditions are suitable, and cooling can be effected without access of air, bright and even mirror-like. It will reflect light just as the polished surface of steel did. There are no signs of crystals or crystallites on that surface, yet, if the sample be sharply broken, the interior is seen to be unquestionably crystalline. The surface or skin, under the effect of surface energy, has failed to crystallize. The forces operating at the surface have been greater than those which directed the marshalling of the interior atoms to form the constituent crystals of the metallic mass. "The skin is not in the solid form; it is vitreous, an undercooled liquid." A further stage may be reached where the presence of a skin or vitreous surface layer is still more clearly evidenced, when the directing crystalline forces operating in the interior have palpably failed to overcome the surface energy effect, and the skin of the solidified sample can be seen wrinkled like a dried bean as it endeavored to accommodate itself to the contracting interior. These wrinkles, like the waves of an instantly frozen sea, are sometimes coarse, sometimes fine. It may be possible to obtain a value for the surface tension by measuring the distance from crest to crest, but much more work must be done before we completely understand the forces operating.

Of the methods available for obtaining quantitative results, the capillary and drop method can be discarded at present, owing to experimental difficulties naturally attendant when temperatures such as that of liquid steel are being dealt with. The solidified drop method is promising, though the difficulties of obtaining drops or globules which have solidified without any constraint other than that of gravity and surface energy are considerable in the case of steel where the access of oxygen might invalidate the results. The few determinations that have been made indicate for steel a value considerably greater than that of mercury. It is perhaps more interesting to discuss now the reasons for the variations in the surface tension which are apparent if not measurable, as the samples progress toward a more complete state of deoxidation. It is known that the occluded gases found in steel profoundly affect its properties when in the solid state, so it was of some interest to determine whether the volume of occluded gases had any relationship to the qualitative values found for the surface tension. As a result of a number of determinations it was found that the volume of the occluded gases was inversely proportional to the surface tension value. At first sight it would appear that this was a clear case of cause and effect, but when it was found that the increase in volume was due to the presence of a larger quantity of the oxygen compounds CO and CO_2 in the occluded gases, it seems preferable to attribute the rise in the surface tension to the gradual elimination of dissolved iron oxide, so that both the increased volume of gaseous oxygen compounds in steel and the lowering of the surface tension are the effect of the same cause, namely, the presence of dissolved iron oxide. With the elimination of the dissolved iron oxide the surface tension value rises, and the occluded gases diminish in volume. Thus the "killing" of steel is not only evidenced by the change in its properties when in the solid state, but its progress can be noted by the rise in its surface tension value, and when experimental methods of the required degree of accuracy are available it may be measured in comparable terms, and possibly as accurately as the surface tension of other liquids.

EFFECT OF UNIFORM PRESSURE ON CHANGES OF STATE.

The effect of pressure on changes of state is taken but rarely into account when metallurgical questions relating to steel are discussed, and its importance is generally overlooked. Yet we have available a number of facts and inferences; carefully devised experiments have been made, while the principles operating are clearly defined and their validity is unquestioned. Metallurgical operations are often directed toward causing a change of state. Solid metals are fused, or the liquid is rendered solid; a change from one allotropic state to another is induced, and its inversion prevented or retarded. These changes always involve an alteration in volume, with the result that great variations in pressure occur which have important consequences in practice. It is only proposed here to deal with the principles involved and their application to a few typical cases, so that their importance might be recognized, and the distinction between the solid and liquid state rendered more clear. The effect of uniform or hydrostatic pressure—that is, cubic compression—is to raise the melting-point, to quote a typical change of state, for all substances except water, gallium and bismuth. These exceptions are significant, for both instances are exceptional in that they expand on passing from the liquid to the solid state. These three exceptions prove the general rule, that substances which contract in volume on freezing have their melting-points raised, while those which expand on freezing will have their melting-points depressed. Extreme pressure will cause ice to melt, and the melting point of bismuth is appreciably lowered if the metal be subjected to pressure. The rule applies to the effect of uniform pressure only. Unequal pressure, involving shearing stresses and consequent permanent deformation, will be discussed later. So far only melting points have been mentioned, but the rule also applies to other changes of state, and, provided that the direction of the volume change is known it can be predicted whether the change point will be raised or lowered by pressure of the nature assumed in the discussion.

The application of the rule to steel will become apparent when it is pointed out that a mass of steel cooling through the critical range, when the change from one allotropic form to another takes place, involves a momentary but appreciable increase in volume; it will be seen that we have a change of state that will have its change point depressed if pressure be applied. Now pressure, in fact considerable pressure, is applied when steel is quenched from its correct hardening temperature, for the volume of steel is greater, and its density consequently less, at high temperatures than low. The momentary increase in volume when cooling through the critical range is but an interruption in the curve of decreasing volume. Quenching has the effect of retaining the steel in its high temperature or metastable state: (1) by the rapid increase of viscosity due to the sudden cooling; (2) owing to the pressure exerted on the interior by the cooled outer layers. Roberts-Austen used a hydraulic press, and also made quenching experiments which demonstrated that the steel in the interior of the mass underwent its allotropic change at a lower temperature, as a result of the pressure applied, as it should from theoretical considerations. The allotropic change involves the momentary de-orientation of the atoms, and this, if the quenching proceeds rapidly enough, might result in a number failing to adjust themselves to the new orientation before the viscosity had increased too much to permit this, and thus a portion of the steel would remain uncrystallized and be in the vitreous or undercooled liquid state. The existence of a vitreous cement at the boundaries of the crystals is now, as a consequence of the experimental work of Beilby, assumed as the basis of a widely-held hypothesis, which so far holds the field. The amount present of this vitreous cement will probably vary with the rate of quenching, and it will certainly vary as the grain size increases or decreases. With under-cooled silicates it has been shown that heating them causes crystallization, and thus the change to the solid form. This necessarily involves the liberation of the heat of fusion; for the undercooled liquid has never, by definition, become solid. It is significant that Cloup found an irreversible evolution of heat at 400° C. when reheating a quenched steel. This, in itself, would not amount to a rigid proof; but he also found the same thing to occur when he reheated a piece of cold-worked steel, and this, as will be seen from the succeeding section, is most important evidence. For the present it will suffice to state that there is evidence that the solid and liquid states of steel are present in a sample at ordinary room temperatures. The spontaneous evolution of heat, noted by Brush, Hadfield and others in the case of quenched steels is but another proof that steels in this condition are in a metastable state. The evolution of heat that Cloup found on reheating such steels represents a further stage in the progress toward a stable state, and indicates relief of the stresses induced by quenching. These stresses are pressure effects, and the evolution of heat, whether spontaneous or as a result of reheating, is a measure of their intensity. The not uncommon fracture, internal or external, of masses of steel when heated or cooled too quickly is another result of the stresses developed.

THE EFFECT OF NON-UNIFORM PRESSURE ON CHANGES OF STATE.

In discussing the effect of non-uniform pressure, attention should be drawn to the work of Johnson and Adams in clearly distinguishing between the effect of uniform or hydrostatic pressure, with which we have so far been dealing, and unequal pressure involving shearing stresses. The distinction is fundamental and of importance when considering the permanent deformation of metals. These writers assume that permanent deformation of a crystalline aggregate, or solid, is due to an actual fusion of a minute portion of the mass along the planes of shearing, with subsequent solidification. But as this re-solidification must occur with extreme rapidity, owing to the abstraction of heat by the surrounding cold mass, there is ample opportunity for formation of a certain amount of super-cooled or undercooled liquid, corresponding to Beilby's vitreous phase, to act as a cement between the distorted or ruptured crystals. This would result in the conversion of the original metallic mass into a conglomerate, with a new pattern in which the extent of the boundaries would be increased, and containing a larger proportion of the vitreous or undercooled form, with a consequent profound change in properties. Non-uniform pressure always lowers the melting-point. That non-uniform pressure should suffice, during the permanent deformation of a solid metal, to cause actual melting of even the minute particles carrying the excess load is admittedly a startling assumption; but the thermodynamical proof is admitted by Roozeboom, Ostwald, Le Chatelier, and Nernst, and questioned by Tamman only. It would appear that the views of Johnson and Adams have considerable support. An ordinary compression test on a short cylindrical-shaped piece of steel affords some experimental evidence. When sufficient pressure is applied permanently to deform the test-piece to, say, half its original height, not only will it have suffered a change of form, but it will have changed its properties. Its tenacity will have increased, its elastic limit will now be higher, it will be less dense, and on reheating an irreversible evolution of heat will occur, as was found by Cloup, at 400° C. This can all be explained on the assumption that a local melting of a small proportion of the permanently deformed material takes place, and that a portion of the melted material is preserved in the vitreous or undercooled state. Without this assumption it will be difficult to find a convincing explanation.

SUMMARY.

1. The properties of an optically clean surface of liquid steel are described, and the similarity to that of a polished metallic surface with a vitreous film pointed out. The preservation of this surface of liquid steel is attributed to the presence of an atmosphere or iron vapor.

2. Means by which the surface tension of liquid steel can be determined qualitatively are described, and it is pointed out that the surface-tension value varies inversely with the volume of gases occluded. It is also suggested that the iron oxide dissolved in the steel is the factor which causes the variation both of the surface-tension value and of the volume of occluded gases. The occurrence of a film of vitreous or undercooled steel on the surface of a sample of liquid steel, if the surface-tension value be high, which has solidified out of contact with any oxidizing agent is described.

3. The distinction between the solid and liquid states is emphasized, and it is shown that fluidity, or the ability to flow under the influence of gravity, is no criterion of the liquid state.

4. The effects of uniform and non-uniform pressure are described, and the differences shown to be fundamental. The former raises the melting or other change-point, except in the case of water, gallium and bismuth. It is shown to follow the general rule that

(*Concluded on page 11*)

Lignum-Vitae, the Vital Wood

The Most Important Single Wood for the American Navy and Merchant Marine

By Samuel J. Record, Professor of Forest Products, Yale University

WHAT woods contributed most to the winning of the war? There was spruce for airplanes, black walnut for gunstocks, oak and hickory for vehicles and gun carriages, mahogany for airplane propellers, yellow pine and Douglas fir for ships. Of these woods and their uses the public has heard, but there is another, one of the most important of all, which has escaped public notice. This is not surprising since this wood performs its duties, silently and efficiently, in the most secluded position imaginable.

The propeller shaft of every battleship, every cruiser, every destroyer, every transport, in fact of every large steamship revolves in wooden bearings. And of all the thousands of woods in the world, just one has been found equal to these exacting requirements. And that is true lignum-vitae, native of the West Indies and certain other parts of tropical America.

This important bearing is in the stern tube in the after part of the ship, next to the screw itself, where only a substance able to withstand great friction could possibly last for any length of time. It sustains not only the enormous dead load of the propeller shaft and that of the propeller, which may weigh as much as 9 tons, but also withstands the terrific impact from the pounding of high seas. And this it will do for years in a submerged position where no external lubricant can reach it except water.

Lignum-vitae possesses certain peculiar properties which fit it for this exacting requirement and unfit it for nearly all the uses to which other woods are put. First of all, it is the most cross-grained wood in the world and comes as near being woven as it is possible for a wood to be. The fibers never run straight up and down the log but weave back and forth in a serpentine manner in thin layers or plies that cross and criss-cross like the corded fabric of an automobile tire. The result is a material of extreme tenacity and toughness.

In most woods used where strength is demanded, cross-grain is a serious defect. For example, in selecting spruce for wing-beams of airplanes the great demand was for straight-grained material and only a fraction of the lumber produced from the choicest trees would meet the requirements. Danger lurked in every cross-grained piece and for an inspector to let such a specimen get past him was little less than a crime. Perhaps at the same time an inspector in a shipyard was condemning a poor grade of lignum-vitae because it was not cross-grained enough!

All of our ordinary woods will float when dry, but lignum-vitae will sink like a stone even when every particle of water has been removed from it. The substance of which all woods are made is about the same and weighs half as much again as water, hence one dry wood is light and another heavy for the same reason that snow is lighter than solid ice.

The lightest wood known will sink like a plummet when it becomes waterlogged, that is, when the buoyant air in its cellular spaces has been replaced with water. Take balso wood, for example, which during the war was used extensively in making the big life rafts so conspicuous on every transport and battleship. Balsa is as light as cork when dry, but unlike cork, which is waterproof, it absorbs water readily when in a natural condition. This tendency is overcome by sealing up the air with a light impregnation of paraffine. Balsa and lignum-vitae represent opposite extremes in tropical woods, nature apparently experimenting to find out how little wood substance she could use in one and how much in the other.

Nature could not make an absolutely solid wood because she had to leave spaces and channels for sap-flow, but she found a way to overcome this difficulty. As soon as the old cells cease to function their every nook and cranny is filled up with a resin which is about a third heavier than water. The result is a material weighing about 80 pounds per cubic foot which is 10 times as much as balsa, 3 or 4 times as much as spruce and 1¾ times as much as white oak. Since lignum-vitæ sells by weight, sometimes for as high as 52 cents a pound, it is obviously a valuable commodity.

It is to this resin content, this after-thought of nature, that lignum-vitæ owes its high rank in the marts of the world. Herein lies the secret of its success as bearings in a most trying position, for this resin serves to protect the wood from the softening effect of water and serves as a natural lubricant to the revolving shaft. The density of the wood enables it to withstand enormous loads; the interwoven fiber keeps it from splitting and tearing apart under impact; the infiltrated lubricant prevents friction and eliminates the danger of an overheated bearing.

The stern tube, in which the propeller shaft revolves, extends from the peak bulkhead in the after-part of the hull to the stern post and, in a large steamship, is usually from 5 to 7 feet long and from 12 to 22 or even 30 inches in diameter. The forward end is made water-tight by means of a stuffing box and flange but the after-end, in the usual construction, is left open to the water.

The stern tube is composed of three parts, namely, (1) an outer steel tube with (2) a brass or bronze bushing or sleeve with longitudinal cleats or retaining strips which hold in place (3) the lining of edge-grain wooden bearing blocks. The number of retaining strips varies in different forms of construction. There may be only one in which case it is located at the upper part of the tube; or two, one at each side; three, one at each side and one at the top; or as many as there are rows of blocks, in some instances 24. In the first methods the lining between the retaining strips is of much the same structure as a wooden-stave pipe, each stave in this case being a row of edge-grain blocks placed end to end, beveled along the side and machined on the faces to fit the bore of the tube.

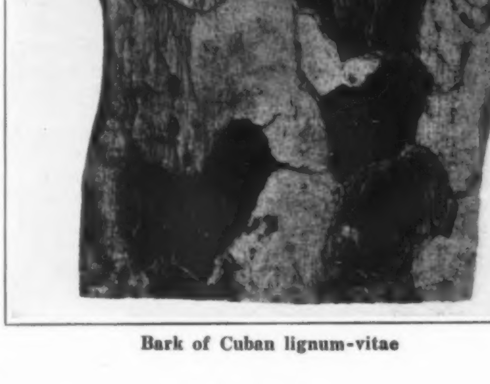
The retaining strips serve not only to hold the blocks in place but also provide grooves into which water enters. The water serves the dual purpose of cooling and lubricating. Where the rows of blocks are arranged in a solid layer it is considered a good practice to cut V-shaped grooves at the joining lines to act as waterways.

There are two principal methods of preparing the blocks for stern bearings. In one the logs are cross-cut into short blocks or "pan-cakes," the thickness (in direction of the fiber) varying from 1 to 2 inches according to the size of the stern tube. These "pan-cakes" are then sawed into rectangular blocks from 2 to 4 inches wide, not less than 4 inches long, the maximum lengths being determined by the diameter of the heart-wood portion of the log. As soon as the blocks are sawed out they are dipped in shellac to prevent checking and warping prior to use.

There is a large amount of waste in cutting out these blocks, being about 33 per cent. in logs 16 inches and over in diameter, about 50 per cent. in those between 12 and 16 inches, and as high as 75 per cent. in the smaller sizes. On this account a minimum diameter of 12 inches is usually specified. It is also claimed that logs of the larger diameters yield better and particularly more resinous wood. The wood close to the pith is avoided because of the danger of checking, while the sapwood is not used because it lacks the necessary resin.

Bark of Cuban lignum-vitae

Bark of Haitian lignum-vitae



Cross section of Guaiacum from Haiti
Note irregular distribution of the pores

Cross section of Bulnesia arborea (Maracaibo)
Note the radial distribution of the pores

In the second method the logs are cut into cants or planks of the required thickness and as wide as the diameter of the heart-portion of the log will allow. These cants are then placed edgewise on an adjustable frame rotating about a fixed center on the table of the band saw. In this way the blocks are cut with the proper degree of curvature to fit exactly into the sleeve. The blocks are then beveled and cut in two lengthwise with a slight taper to permit "fox-wedging" into place. This method of fastening in the blocks is shown by the cross-section below.

After the blocks are fitted, wooden strips are temporarily placed in the grooves, and the tube is fixed in a lathe and bored out to the exact diameter required to fit the propeller shaft. To prevent the blocks drying out and checking or getting loose the tube is kept filled with wet sawdust and shavings until permanently installed in the ship.

The life of a ligum-vitæ bearing is said to be about 10 years. If the propeller shaft is out of alignment it may wear out the bearing in two years or less. The greatest wear is sustained by blocks in the lower part of the bearing since these support the most of the weight, not only of the shaft, but also of the propeller which may be as great as 9 tons. When to this dead load is added the impact of the waves it is obvious that only the densest and most tenacious woods would be able to withstand the enormous strains produced. Various woods have these properties but none other than ligum-vitæ combine with them the natural lubricant indispensible to the prevention of heating and rapid attrition.

Small bushings are sometimes bored from solid wood instead of being built up. The process of manufacture of the so-called "patent feathering wheel bushings" which are used on certain side-wheel steamers is as follows: The logs are cut into bolts 16 to 18 inches long, slabbed to an octagonal form to remove the sapwood, and then turned in a lathe to a diameter of 5 1/16 or 5⅞ inches. These cylinders are then cut into 7-inch and 8-inch blocks and the centers bored to the required size.

The manufacture of stern bearings calls for the highest quality of logs and these now command a price of from 12 to 18 cents, mostly 14 to 16 cents, per pound. At 15 cents a pound, a cubic foot weighing 80 pounds is worth $12. In some instances lignum-vitæ has been sold for as much as 25 cents a pound or about $20 per cubic foot.

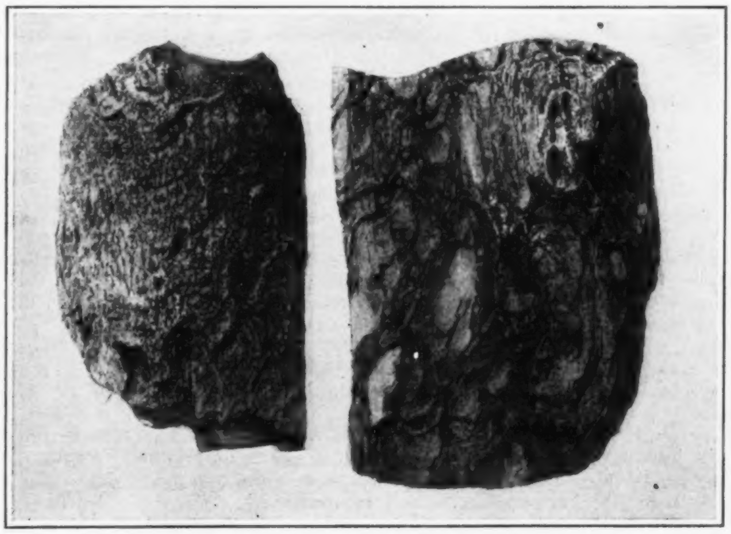
Stern bearings provide the most important use for lignum-vitæ but by no means the only one. Formerly it was in great demand for bowling balls but now only about one ball in ten is made of wood. The value of the lignum-vitæ block from which a "regulation" ball is cut is about $2.50 and the manufacture requires much skill and painstaking effort.

A large quantity of low grade logs, known as "cutting up" wood, is consumed in the manufacture of rollers for furniture casters. Small round sticks make excellent mallets and fill a large demand, especially in England. Another important use is for sheaves of pulleys, and they have been known to last in constant use for 70 years. Wooden sheaves are never used with steel cable or wire rope. Another nautical application is for "dead-eyes," a small flattish block with a grooved rim to fit in the bight of a rope or encircled by an iron band, pierced with three holes to receive a lanyard, and used to extend the shrouds and stays.

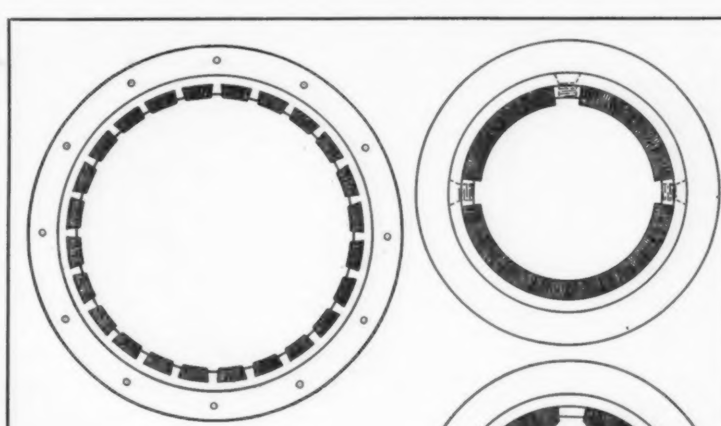
Among the miscellaneous uses may be mentioned stencil and chisel blocks, watch-makers' blocks, mortars and pestles, dowels, golf-club heads, wooden cogs, water wheels, and block guides for band saws. In building the Panama Canal, the true lignum-vitæ made the most serviceable railroad cross-tie that could be obtained. If not spiked to death, such a tie will last 30 years under the most trying conditions.

Between 150 and 200 tons of genuine lignum-vitæ are used every year in New York for fuel in grate fires. The very dense nature of the wood together with the heavy resin content produces a fuel with intense glowing heat and of good lasting qualities. This provides one outlet for the defective and crooked logs which are to be found in every shipment. The selling price, delivered to residences, is about $25 a ton.

The sawdust or flour obtained in cutting up the wood in manufacture is in demand by the drug trade at a price varying from $20 to $40 a ton. From this the resin is extracted and while some of this finds its way to the druggists' shelves to fill an occasional prescription for gout or rheumatism, its principal demand is in the manufacture of the compound decoction of sarsaparilla. There is nothing in its present lowly estate medicinally to suggest the glory of earlier days when it was hailed as a panacea of all man's ills and commanded as much as seven gold crowns a pound. Here is the story:



Bark of Nicaraguan lignum-vitae
The wood is used in the United States, but not in Europe



Cross sections of stern tubes of different types

At left a large stern tube with waterways between the strips of lignum-vitae blocks. Below a strip of blocks in position showing lengthwise cut to permit wedging into place.

At right: above, section of tube of a steam trawler showing solid lining with 3 retaining strips and waterways; below, section of a small tube, with single retaining strip at top and grooves for waterways cut between the blocks.

Some 400 years ago Gonsalvo Ferrand, a Spanish explorer found in the West Indies a squatty, thick-boled tree with a wood reported by the natives to have great curative powers. The mind of the visitor was ripe for miracles and here was the beginning of one. When his ship returned it carried in its hold a few short logs of this wood the medicinal virtues of which waxed mightily with every re-telling.

Arrived in Europe this wood met instant favor with the medical fraternity and was hailed as a god-send to humanity. From the New World had come a remedy for such great scourges and maladies as lues venerea, leprosy, scrofula, palsy, epilepsy, gout, chronic rheumatism and many other diseases. Learned treatises began to appear as early as 1517 and were many times reprinted and translated. There was no dearth of testimonials to its curative powers, and the many failures were ignored or explained away.

This wood was called by the natives "guayacan," but the Europeans re-christened it "lignum-vitæ," the wood of life, and by this name it is still known throughout the timber markets of the world. The old name, latinized to *Guaiacum*, is retained for botanical and pharmaceutic purposes.

Lignum-vitæ is today medicinally obsolete. The one ingredient to which it owed its healing power has been lost, and that ingredient is *Faith*.

Lignum-vitæ's present value and reputation are founded on more substantial and enduring grounds. For its more important uses no satisfactory substitute has been found. This brings up the question of supply. How long will the present source hold out and what new fields are awaiting development?

PRESENT SOURCES OF SUPPLY.

Several different kinds of lignum-vitæ are recognized by the trade and they are usually designated by the name of the country or the port of origin. The principal kinds now found on the New York market are Cuban, San Dominican, Jamaican, Haitian and Nicaraguan. Others less common are Bahaman, Mexican and South American. Buyers generally specify the kind of wood they want and their likes and dislikes are usually very decided. To what extent these opinions are based on facts and to what extent they are mere prejudices the writer has been unable to determine, but they do exist and exert a very material influence on the market and have a very important bearing on the question of future supply.

Cuban lignum-vitæ is considered the standard, at least for the larger sizes. The logs are mostly 4 to 8 feet long with a few of the smaller sizes 10 feet. The diameters range from 6 to 24 inches with only a small percentage over 16 inches. Logs of assorted sizes have recently been sold alongside the railroad in Cuba for as high as $135 a ton. Most of the Cuban wood is obtained from Oriente Province in the eastern part of the island and is shipped from Santiago. According to a Commerce Report of 1917 not more than 4,000 tons remain in accessible places, not more than one-third of this would repay the cost of getting it out, and the total supply is in danger of early exhaustion. A New York dealer questions this statement and cites the fact that a single operator in this region got out 1,000 tons in 1918 and that others were also engaged in the business. There is also some wood in the Pinar del Rio Province in the western part of the island but it is not now being exploited. There is plenty of Cuban lignum-vitæ available now but only continued high prices will justify the difficult logging of the remaining standing timber.

The lignum-vitæ from Jamaica, Bahama Islands and Porto Rico is small, usually not exceeding 5 inches in diameter. It is of good quality and is chiefly in demand for mallets. The supply is limited but will last for many years if the demands upon it are not heavier than they have been.

There are two distinct grades of wood from the island of Santo Domingo. That obtained from the Dominican Republic is recognized as genuine and has the characteristic bark and other features of the Cuban. The logs now reaching the market are from 2 to 3 feet long and mostly 4 to 10 inches in diameter. It is said that much larger wood than is now being obtained is available in considerable quantity in this country, but that the natives lack the necessary facilities and roads for getting it out. This is a promising future source of supply and some wood users consider the wood fully as good if not better than Cuban.

Lignum-vitæ is scattered over the whole of Haiti, but most of it that reaches the market is considered by dealers and users as non-genuine and is often called "bastard lignum-vitæ" in the trade and "vera" or "bera" locally. It is unquestionably a species of *Guaiacum* and not of the closely related genus *Bulnesia*

(*Continued on page* 15)

The Strongest and Most Durable Fiber*

The Cultivation, Preparation, Spinning, Weaving and History of Flax

By W. Norman Boase, C. B. E., Chairman of the Scottish Flax Spinners' and Manufacturers' Association

The origin of the flax plant (*Linum usitassimum*) is doubtful, and like most plants which have been long under cultivation it possesses numerous varieties. It is an annual, with an erect stalk rising to a height of from 20 to 40 in. and branching at the top, each branch ending in a regular and symmetrical flower, usually of a bright blue color, though Friesland flax and some Dutch flaxes have a white flower. The fruit, or boll as it is called, is round, containing five cells each, subdivided into two, thus forming ten divisions, each of which contains a single seed. The seeds are oval in section, and are heavy, smooth and glossy, and greenish-brown in color.

The earliest cultivated flax was *Linum augustifolium*, a smaller plant with fewer and narrower leaves than the *Linum usitatissimum*, and usually perennial. This is known to have been cultivated by the inhabitants of the Swiss lake dwellings, and grows wild in Africa and Western Asia, and in Southern and Western Europe, including England and the South of Scotland. The annual flax (*Linum usitatissimum*) has been cultivated for probably five thousand years in Mesopotamia, Assyria and Egypt, and grows wild in the districts included between the Persian Gulf, the Caspian Sea, and the Black Sea. This annual flax was probably introduced into Northern Europe by the Finns, afterwards into Western Europe by the Western Aryans, and possibly here and there by the Phœnicians, lastly into Hindustan by the Eastern Aryans after their separation from the European Aryans. The cultivation and preparation of flax are among the most ancient of all textile industries, and there are preserved to the present day distinct traces of their existence during the Stone Age.

Flax was most extensively used and variously applied in the lake dwellings. Unfortunately, although rough clean flax ready for use has been found in the lake dwellings, we can form no idea of how it was prepared or cultivated; it is known, however, that it was used for making lines and nets for fishing and catching wild animals; cords for carrying earthenware vessels and other heavy objects—in fact, one can hardly imagine how navigation could have been carried on, or the lake dwellings themselves made, without cords and ropes; and the erection of the dolmens and menhirs—possibly even of the Pyramids themselves—would have been almost impracticable without the use of strong flaxen ropes.

Flax fibre, which is probably the strongest and most durable of all vegetable fibres, certainly occupied a most important place in Egypt, and its uses are frequently referred to in the Bible.

Linen was always chosen where cleanliness and purity were required, and was invariably worn by the priests. The high priest's ephod and mitre, as well as the turbans and robes of the priests, were made of fine linen, and when these garments became worn out they were unravelled to make wicks for the lamps at the Feast of Tabernacles.

It is interesting to recall that one of the plagues of Egypt was the destruction of the flax crop by hail, and the recent taking of Jericho reminds us of how Rahab hid Joshua's spies with the stalks of flax which she laid in order upon the roof.

Research has brought to light also several curious grottoes and tombs in Upper Egypt, covered with paintings as distinct and brilliant as when first executed, illustrating with remarkable fidelity and minuteness all the various flax processes, pulling, steeping, scutching, spinning and weaving.

Flax was probably first brought to this country by the Romans, who had a factory at Winchester; but although it is known that linen fabrics were fairly common in England, there is little reference to them to be found till the end of the twelfth century, when evidently the crop had attained considerable dimensions, as it was included among the titheable articles. In the middle of the sixteenth century, owing to imports (including linen) having increased very much, and many people being idle in consequence, Henry VIII. passed an Act compelling farmers to grow flax to the extent of one rood for every sixty acres cultivated. Thirty years later this Act was made more stringent, and all farmers not growing one acre of flax out of every sixty acres cultivated were fined £5.

Further methods of increasing the area devoted to flax were adopted towards the end of the seventeenth and beginning of the eighteenth century, when the amount of tithe was reduced, a bounty was offered on all exported British-made sail cloth, and laws were passed compelling people to wear linen hat bands and scarves at funerals, and to bury their dead wrapped in plain linen. It is not easy to discover what was done in Scotland regarding growing flax in these early times; but one Roman historian refers vaguely to the Caledonians using some linen apparel. He states they lived in a state approaching nudity, but does not indicate whether this was from choice or necessity. Knowing our climate we must form our own conclusions.

In very early times in our Highlands women went with their heads bare until after marriage, when they wore a linen mutch, and early in the fourteenth century linen was assuredly in considerable use; indeed, it is given some credit for helping to win the Battle of Bannockburn, as history relates that "the women and camp followers put on shirts, smocks and other white linens and bound flaxen towels and napkins on staves, and, making a great show, came down the hill in face of the enemy with much noise and clamor, whereat the English, supposing it to be a reinforcement, turned and fled."

In 1711 a Board of Trustees was established in Ireland, and in 1727 a similar Board was appointed in Scotland for administering annual sums for the encouragement of manufacturers, and premiums were given for weaving and spinning, as well as for growing flax. These Boards did much good, certainly to begin with, in fostering the linen industry.

The flax industry was at this time on what might be called a domestic scale. Most farmers and landowners grew flax or lint, as it was often called, in small patches, and it was prepared, spun, and woven on their own premises, or, after being spun, was sent to the village webster to be woven.

This practice kept the industry away from any motive to apply labor-saving devices, and it was only by slow degrees, when stimulated by the Board of Trustees and others, that machinery was invented and mills were established.

Towards the end of the eighteenth century many proprietors introduced a clause in the lease of farms restricting the amount of flax to be sown.

They held that flax was a dirty and exhausting crop; and as probably the flax was not sown on clean land nor in the best rotation, and very likely the seed itself was not properly cleaned, there may have been something in their contention.

The maximum acreage under flax in England was in 1870, when 24,000 acres were cultivated. Seven years later this fell to 7,000 acres, and thereafter decreased steadily and gradually. The average for 1881 to 1890 was 2,900 acres; for 1891 to 1900, 1,300 acres; for 1901 to 1910, 480 acres; and prior to war the acreage was only between 200 and 300.

In Ireland the first record is 58,000 acres in 1874, rising to 174,000 in 1853, and falling to 97,000 in 1856. The maximum was reached in 1864, when 102,000 acres were sown, but this was immediately following the cotton famine, and the acreage dropped the following year to 251,000 and to 122,000 in 1872. Between this time and 1890 it fluctuated considerably, the highest being 157,000 acres in 1880, and the lowest 89,000 in 1884. Thereafter it declined with fluctuations, the average between 1896 and 1910 being 48,000, the lowest being in 1898, when only 34,500 acres were sown The last five years' acreages have been:

	Acres.
1914	49,253
1915	53,143
1916	91,454
1917	107,566
1918	143,355

The reason for the violent character of the fluctuations in pre-war days in Ireland is that flax is not an essential part of the rotation of crops. Temporary grass, grain, and green crops in systematic rotation are essential to husbandry, as they are necessary either for the cleaning and amelioration of the soil or for the maintenance of stock kept upon it. Flax is not required for the one or the other, and the farmer grows it very often as a stolen crop between two of the staple crops when he happens to have a piece of ground specially suitable for its growth or when prospects of a good price for fiber are attractive.

In Scotland the area under flax reached its maximum in 1854, when 6,670 acres were sown. Three years later the figures had fallen to 1,534; thereafter it dwindled and died down almost entirely till 1885, when an endeavor was made to resuscitate the sowing in Fife; scutching plant of modern type was put down and warm-water retting introduced. In 1887 about 900 acres were under cultivation, but success did not attend the endeavor, and the crop soon went practically entirely out of cultivation.

In examining those figures it is well to remember that the term flax is used to denote the crop grown for linseed as well as the crop grown for fiber, and the acreages mentioned include for England and Scotland both these crops, whereas for Ireland, where flax for linseed is not grown, the figures are the flax fiber crop.

Briefly, the reasons for the decline of flax cultivation for fiber were the introduction of cotton and the successful spinning of that fiber, the importation of large quantities of Russian flax after the Treaty of Paris in 1856 and peace with Russia had been declared, the centralization of the linen trade in a few districts only, which deprived farmers of their local markets, and the fact that whenever prices for grain were remunerative farmers were glad to be relieved of the troublesome after processes of flax preparation. The production of flax has been very considerably reduced during the last thirty years in all European countries except Russia.

		Acres.		Acres.
Belgium	1893	91,993;	1909	39,288
France	1894	81,965;	1909	50,511
Holland	1890	40,780;	1913	36,185
Rumania	1902	102,117;	1910	33,103
Austria-Hungary	1898	197,373;	1913	89,913
Germany	1880	319,396;	1900	83,147

It has been impossible to obtain figures for corresponding years for the various countries, but generally it may be accepted that in the above six countries the total acreage under flax was, prior to war, probably less than half what it was thirty years previously.

Russia is by far the largest flax-producing country in the world, and, unlike other European countries, the cultivation of flax did not decline in pre-war years. On the contrary, it tended to increase, but no very reliable statistics can be obtained because a large quantity of flax is grown by the peasants for their own use and in very small quantities of an acre or less. Probably a conservative estimate is that prior to the war Russia had under flax cultivation 3,800,000 acres, producing 525,000 tons of flax fiber, of which she exported to:

United Kingdom	86,400	tons.
Belgium	60,500	"
France	34,700	"
Germany	60,400	"
Austria-Hungary	22,000	"
Total	264,000	tons.

These export figures are for ten years pre-war average. In 1913 Great Britain and Ireland imported 102,443 tons of flax fiber made up as follows:

Russia	81,567	tons.
Belgium	18,006	"
France	278	"
Holland	1,668	"
Germany	519	"
Other countries	405	"

Ireland in the same year produced 12,652 tons, and it may therefore be assumed that the United Kingdom used from 100,000 to 110,000 tons of flax fiber, of which between 80 and 90 per cent. was imported.

Some years before the war the British Flax and Hemp Growers' Society was formed, to administer a grant from the Development Fund for the purpose of conducting experiments in the cultivation and separation of flax and hemp fiber in order to ascertain the commercial possibilities of these industries in Great Britain. Experimental stations were started at Yeovil and at Selby, a few hundred acres of flax were grown, much most excellent research work was done, and this work, as far as was possible, was continued even during the war.

We were dependent on Russia for about 80 per cent. of the flax fiber we used, and when in 1917 the Russian Revolution broke out, and the Baltic Provinces and the

*From *Jour. Roy. Soc. Arts* (London).

water-retted flax districts of Russia were overrun by the Germans, it was realized that we were faced with a great shortage of flax, and that it was necessary to increase the acreage in this country as quickly as possible, not only because of the industry, but because flax goods, such as aeroplane fabrics, Royal Navy canvas, tent duck, etc., were urgently required for the carrying on of the war. Ireland was able to respond to the necessity by increasing the area under flax in 1918 by 36,000 acres, and the Boards of Agriculture in England and Scotland, assisted by the British Flax and Hemp Growers' Society, arranged for nearly 14,000 acres being grown in England and Scotland. Very great credit indeed is due to the Boards of Agriculture and to the Flax Growers' Society and also to the Office of Works, which has been associated with them, for the energy and efficiency displayed in the growing, harvesting, and preparation of flax in Great Britain, and for the success obtained in spite of at times almost overwhelming difficulties.

We are still faced with a probable world shortage of flax, and although happily the necessity for war materials has ceased, the flax trade, owing to the shortage and the very high price of material, is in a very precarious position at the present time. Difficulties, however, are only created to be overcome, and it is to be most fervently hoped that troubles in Russia will soon cease and we shall therefore be able to procure some of the flax which certainly is still there. Meantime, by encouraging the growth of flax in our Empire—a matter which is presently engaging the attention of Government—it is hoped we shall, in the not very far distant future, be able materially to augment, if not entirely supply, the fiber needs of the flax industry.

CULTIVATION.

Flax can be grown on any good medium land, but the land must be clean; light or sandy soil and heavy clay land are not suitable. But the selection of the land is not nearly so important as its proper preparation prior to sowing the seed.

The land must be deeply worked and firm, with a shallow surface layer to cover the seed after sowing. This is important, as the crop grows very rapidly, the growing period only extending over eleven to thirteen weeks. The success of the flax crop depends mostly on the proper preparation of the land, and on the seed employed.

In the rotation of crops, one of the best periods for the introduction of flax is soon after the land is broken up from grass. It does well immediately after newly plowed pasture, as it is little affected by wire worm, but it can also be grown after oats, roots or potatoes.

The land must in every case be well harrowed and rolled, to obtain a fine tilth and an even surface, so that the straws may be of similar length.

Flax has generally been looked upon as a dirty and exhausting crop, but if good, properly cleaned seed is sown it cannot be a dirty crop, and numerous tests have proved that the amount of plant food it takes from the land is very similar to that taken by oats and wheat.

The truth probably is, that as flax is pulled and not reaped the land looks dirty, because all the weeds are left standing in the ground, and although it is really not an exhausting crop, it certainly is a non-restorative crop, and the seed being saved for sowing, and the straw for fiber nothing goes back to the land.

In Canada and British East Africa flax is looked on as one of the best crops for clearing the land, and very good crops of grain are often got after several successive crops of flax on virgin soil.

Artificial manures, judicially used, give good results; potash is much used in Ireland, and a light dressing of sulphate of ammonia is beneficial on some soils, though as a rule, if the ground selected for sowing is in good heart, no manure is necessary.

The sowing is best done broadcast, at the rate of about two bushels to the acre, and the time for sowing varies from the third week in March to the end of April.

After sowing, the seed should be covered by harrowing with a light harrow, with closely set teeth, and then lightly rolled. When the plants are about 3 inches high the land should be weeded. If the flax has been sown on really clean land, this will not be an arduous task, as only large weeds, such as charlock, docks, and thistles will require attention; but if the land is dirty the weeding is a most tedious process. When flax is sown for seed only, it is allowed to come to maturity, but when sown for fiber it is harvested before it is ripe, when the lower part of the stem is changing color from green to yellow, and the leaves to about half-way up the stem have changed color and fallen; at this stage the seeds are also changing in color from green to a greenish-brown. If harvested at this time the best results can be got, both for fiber and seed, as the seed matures and ripens on the stock. If it were harvested when it had come to maturity, the seed would be good; but much of the natural sap in the straw would be lost.

Most flax-growing countries have been dependent upon Russia for the supply of seed, and in this country we have used mostly Pernan Crown, a Russian seed, and Riga Child or Riga Grandchild, these being Russian seed sown for two or three seasons, generally in Holland, and often called Dutch seed. The germination should be 90 per cent., and the purity 98 per cent. It is very essential to sow only seed of good germination and great purity.

HARVESTING.

Flax is pulled, not reaped or cut, the reason being that if cut all the weeds would be cut with it, and this would cause endless trouble and deterioration to the fiber in the further preparation. Up to the present time this pulling has been done entirely by hand, a lengthy and tedious process; but several pulling machines have recently been invented, and although these are presently hardly more than in their experimental stages, without doubt they will in the near future be perfected, and will revolutionize the growing of flax for fiber in this country.

When flax is pulled, the straws of similar lengths must be arranged with stems parallel and tied up into neat bundles or small sheaves by twisting a few of the stems round them below the seed bolls. These sheaves are then set on end in the field to dry, and to allow the after ripening of the seed, after which the crop is put into a rick or the seed taken off.

There are several methods of removing the seed from the straw: *By rippling*—that is, drawing the bolls off through a vertical iron comb. The collected bolls can subsequently be passed between rollers or flailed to remove the seed. This rather tedious method has the merit of leaving the flax straw in the best condition for subsequent operations, and as the bolls are unbroken the seeds of weeds can easily be removed.

By deseeding—that is, passing the top end of the straw between revolving rollers set so that the straw is hardly touched, but the seed capsules are crushed sufficiently to free the seed without damaging the straw. The advantage of this method is that the bolls are separated from the straw and the seed threshed at the same time.

In parts of Russia and Belgium the straw is spread in rows on a smooth floor and the bolls beaten with a wooden mallet. It is very unlikely, however, that this primitive method will continue to be practised. A certain amount of success has been attained by using an attachment on an ordinary threshing machine whereby the straw is debolled, crushed, winnowed, and cleaned, and it is extremely probable that some such method as this will be perfected which will by treatment where the flax is grown save the loss of seed which at present occurs when the undeseeded straw is stacked sometimes both at the farm and at the deseeding station.

RETTING.

After the flax is deseeded it is stored in readiness for the next process, retting or rotting, which is an operation of the greatest importance and one in connection with which many experiments have been made, and many and various processes brought forward to remedy the defects of the primitive methods, and, if possible, to accelerate the time required for properly rotting the fiber. A certain amount of success has been attained, but it has been found that the nearer one can approach to natural methods the better the result, and the use of chemicals or the boiling of the straw or such-like methods only result in poor fiber being produced. There are two processes of retting—dew-retting and water-retting—and in both the action of heat and moisture sets up fermentation, which separates the fibers fro mthe core, to the outside of which these are attached by a gummy or resinous matter called pectose.

The method of dew-retting is to spread the fiber on grass where it comes under the influence of rain, sun and dew. The fiber is spread thinly over the ground in regular rows, and turned over often so as to get a uniform decomposition. This process is tedious, but if properly attended to and the weather is favorable, very good results are obtained, the fiber being soft and silky. The method of water-retting is to immerse the straw in canals of slow-running streams and allow fermentation to take its natural course.

The finest flax we know, Courtrai flax, is retted in the soft warm water of the slow-running Lys, along whose banks so many notable battles have recently been fought. We have not any such river, but similar results can be obtained by warm water retting in tanks. These tanks, which must have no lime in their composition, are generally made with a false bottom. The flax straw is placed vertically in the tanks, the root ends downward, and beams are placed on top to keep it down. The soluble substances and dirt from the roots are dissolved and washed out of the straw by the water and sink through the false bottom. The flow of water can be regulated so that the motion is slow, and the liquids of different densities do not mix; an overflow is also arranged for at the top of the tank.

Modern experiments have shown that very good and even retting can be done by keeping a constant slow flow of water heated to a temperature of about 70 to 75° F. This appears sensible, as it is about the summer heat of water. Retting at a higher temperature tends to injure the fiber, although it must be admitted that excellent results have been obtained in recent years with water at 95° F., but care has to be taken not to over-ret. At a temperature of 70° to 75° F. the time taken for retting is about seven days. Flax should never be retted below 60° F.; if it is, a very coarse, harsh fiber results. Friesland flax is said to be retted in brackish water, but all other flax is retted in fresh water.

After the flax is properly retted, this being determined when it is found that the fiber separates easily from the woody core, it is lifted from the tanks and the water allowed to drain off for a few hours. When first taken from the steep it is soft and spongy, but soon hardens sufficiently to be moved to field or shelter for drying.

In summer the straw is easily dried by standing it in beets in the open, but in our uncertain climate it is better to provide shelter from rain and wind. Many experiments have been made in artificial drying, but although it is believed this can now be accomplished without injuring the fiber, it has yet to be proved that it can be done economically. When properly dry the flax is passed between rollers to break the woody core, which can then be more easily knocked away from the fibre, and this is done by the final cleaning process called "scutching," and the better broken the straw is the easier will be this final process.

SCUTCHING.

The ordinary method of scutching is performed by taking a handful of retted and broken straw, called a strike, holding it over an upright board, and striking it repeatedly in a downward direction with a thin wooden blade held in the other hand.

The more modern method is to have the wooden blades on a power-driven revolving shaft; the scutcher feeds the strike which he holds in his hand over a rest, and when one end has been properly cleaned he reverses the strike.

These scutching mills are very simple and save much labor. The wooden blades or swords, generally five in number in Ireland and up to twelve in Belgium, are fixed on the power-driven shaft every few feet, and opposite each stall which is occupied by a scutcher. The whole is closed over with wood, and the dust, etc., can be removed by means of a fan. A certain quantity of fiber is knocked out of the strikes along with the wood, and this is called tow or codilla, which is partly rescutched and graded. The wood and the dust can be used as fuel for heating the water for the tanks. The flax fiber obtained from these operations is then made up in bales ready for the spinning mill. Before leaving the preparation stages it is well to state that in the working of flax the best results are got when the fiber is given a rest between each and every process.

YIELD.

Flax when grown for seed only is sown thinly, about one-half to three-quarters of a bushel per acre, and the plants have room to branch, and give more capsules and seed; but when grown for fiber it is sown much more thickly—about two bushels to the acre—necessitating the growth of a straight stem, which is essential for good fiber. Grown for fiber at two bushels per acre, the yield on an average on fair land will be 2½ to 3 tons of straw and seed, and this will probably give roughly 6 cwt. of seed, 4 cwt. of scutched flax, and 1 cwt. of scutched tow, the balance being waste which, however, is not all lost, as much of it can be used in the furnace for heating the water for steeping. The water from the retting tanks is also useful as a liquid manure.

(*Concluded in Suppl. No. 2272*)

Flower Camouflage

Peculiarities of Some Wild Flowers of Southern California

By Francis M. Fultz

"Things are not always what they seem" is as true in the Flower Kingdom as anywhere else in the world.

Few ever stop to think that plants may have good reasons for putting on disguises, or even that they resort to such a practice. And so it happens that many a time we are very neatly fooled. Some of the "smoothest" jobs of camouflage ever "put over" on an unsuspecting and confiding public are to be found among those practiced by the flower creation. We may get a good idea of how neatly this is done by taking a close look at some of the plants about our houses and in our gardens; for a number of our cultivated plants try to make us believe their flowers are something very different from what they really are. I might say on the side, as far as most of us are concerned, that they manage "to get by with it."

The Bougainvillia is one of this sort. What most of us take for a bright-magenta, three-petaled, pyramid-shaped flower is really a group of three brownish, rather inconspicuous, tube-shaped flowers, each one of which is neatly hid by a large magenta-colored bract that is part of the flower-stem. When we look at a mass of Bougainvillia vines on the side of a house, or covering a pergola or trellis, and bright with magenta, it is the highly-colored bracts which we see, and not the flowers at all.

The Poinsettia is even more successful with its flower-pretenses, although it doesn't try to cover up its real inflorescence. The camouflage it puts on is so brilliant and overpowering that we overlook the real flowers, although they are right there in plain sight. Many persons at first positively refuse to believe that the bright scarlet rays are nothing but leaves. Yet that is what they are—a circle of leaves surrounding a cluster of small flowers which are so lacking in beauty and attractiveness that we wouldn't have them around, if it weren't for the false dresses they wear. I think all who know what the real Poinsettia flowers are will agree with me in declaring that they are entirely justified in borrowing some plumage in which to shine; and, also, that they make a thoroughly good job of it.

It is easily seen that the camouflage of flowers is for a very different reason than that practiced by humans. We try to hide ourselves by means of it, but flowers use it as an advertisement of their presence. By means of it they hang out a blazing sign which bees, butterflies, and their other insect-friends can see from afar. At least most plant camouflage is of this sort, for nearly all the flowers which practice it have been denied by Nature the possession of a corolla. Their efforts at camouflage are largely in the direction of substitutes for this bright part of the floral dress which they lack. In trying to make up for the deficiency, those flowers which have a calyx develop that part of the floral dress in size and color until it resembles a true corolla. Where the calyx, too, is wanting, the bracts at the base of the flower, and sometimes the leaves further down the stem, are drafted into service.

Then there are some flowers which practice a sort of camouflage, although they already possess an attractive floral dress. This kind consists of an abundant growth of colored involucres, or whorls of bracts, which in some cases almost smothers the flowers, and often quite outshine them. It isn't always clear just why the plants put on this style. And, from the human point of view, the beauty of the flowers is not always thereby enhanced. In fact, to our way of thinking, the added floral garments often mar the attractiveness of the flowers. But of course Nature has a different point of view.

A good many of our wild flowers are just as diligent in camouflaging themselves as any we have in our yards and gardens—and just as successful, too. And we cannot deny that most of them which practice the art have very good reasons for wanting to dress up in borrowed finery—because of the unattractiveness of the real floral gown, or perhaps the want of it altogether.

One of the most signal successes must be credited to the Yerba Mansa (*Anemopsis californica*). Its name is Spanish, and means the "tame herb." Just why it should have been so called no one seems positively to know. Perhaps it may be because it so readily lends itself to man's use in a medicinal way. I notice that Saunders, in his "Flowers and Trees of California," suggests that the name may have come from "Mansos"—name for the domesticated Indians, i. e. tame Indians, among whom the plant was a sovereign remedy. The peppery root has very astringent properties, and the Spanish, as well as the Indians, used a decoction made from it both externally and internally. They also used the leaves, in the form of a decoction or a poultice for rheumatic ailments.

Yerba Ma sa (Anemopsis californica)
The white "petals" are nothing but bracts. A masterpiece of camouflage

The Yerba Mansa lives only in semi-marshy places—"cienagas" of the Spanish—preferring those which are somewhat saline ar alkaline. We often see the low-lying places near the ocean covered with its dock-like leaves, and dotted with what seems to be flowers of generous size and commendable beauty. Apparently there is a circle of from six to eight large white petals, from the center of which rises a greenish, conical, fleshy spike—the combination reminding me, except for the color, of a Mexican sombrero. But these white "petals" are only camouflage. They are nothing but bracts serving as a floral dress for a whole family of small, naked flowers that are half-buried in the fleshy spike—not quite naked, either, for each has a small greenish bract at its base; but no petals or sepals.

The Yerba Mansa is interesting in a botanical way, because it is the only representative of the Lizard-Tail Family—the family got its name from the appearance of the scale-adorned spike that belongs to the flowers of this group. There is but one other species in North America, that I know of, the "Lizard's-Tail" of the Eastern States. Both species are "outlaws" as regards allegiance to some definite number scheme, having 6, 7 or 8 stamens, and either 3 or 4 stigmas.

There are other interesting things about the Yerba Mansa, but I must pass them by for I have already wandered far enough away from the subject in hand—flower camouflage. So I shall pass on to the Four-O'clock Family, a group which will keep me close to the subject, and give me plenty of material to gossip about.

California Wild Four O'Clock (Mirabilis californica) What appears to be the corolls is really the calyx. There is no corolla

The Four-O'clock Family includes the Four-O'clocks and Sand-Verbenas. They are a charming group, although Nature has failed to provide any of them with a corolla. She has squared herself for this oversight, however, by permitting them to change the size of the calyx, and to tint it with such bright colors that most of us never know they are short one floral garment.

We should be particularly proud of the Four-O'clocks, for they are flowers of the South. They are evidence that our climate is sub-tropical, or at least nearly so. None of the family is found in the East—except the garden Four-O'clock in cultivation, and that has been brought from the Tropics, where there are numerous species. There are some nine or ten species in the Great Southwest, of which California has two Four-O'clocks and four Sand-Verbenas.

Our two Four-O'clocks were originally placed in the same genus with those from the Tropics—which is *Mirabilis*, the "wonderful"—and they are still regarded by some botanists as belonging there; but there are others who have a brand-new genus for them, *Hesperonia*. However, they are just "Four-O'clocks" to the common run of us. And most persons don't know they are of two different species. They have vine-like stems from a woody base, but they are not climbers. We might rather call them clamberers. They run over brush piles and stone heaps, and often make a very pretty display of both foliage and flowers.

Like the Evening-Primroses, the Four-O'clocks are night-bloomers, although they also appropriate part of the daylight. On sunshiny days they open late in the afternoon and close about eight or nine in the morning. On cloudy days they never completely close, and if the sky is dark and lowering they may remain wide open all day. Our wild Four-O'clocks have open, bell-shaped calyxes, with wavy, crinkly margins that give them a very pleasing effect. They vary in color from pinkish-purple to magenta. Red-magenta is the prevailing shade. The stamens project from the bell, and gracefully lop over toward the lower side. This is one

of the distinctive features of the Four-O'clock "style" that we first notice, and which helps us to distinguish Four-O'clocks from other flowers.

Now for the Sand-Verbenas. In the first place these flowers must not be confused with the true Verbenas, which belong to the Vervain Family, and which are not nearly so showy nor attractive, although they have the full floral dress of calyx and corolla.

Our southern California Sand-Verbenas go under the botanical name of *Abronia*. Two of them live along the beaches, and the other in the desert and semi-desert places of the interior. They are known as "verbenas," or "sand-verbenas." The desert species is sometimes called "Wild-Lantana," from a fancied resemblance of its flowers to those of the lantana shrub of our dooryards. But it is in every way a more pleasing flower than that of the lantana. It is a delicate pink-lilac in color, and has an agreeable fragrance. The individual flowers are not large, but they are in clusters of from ten to twenty ;an das the clusters are often

Beach Sand Verbena (Abronia umbellata)
The showy part is the calyx. It takes the place of the absent corolla

thickly set along the vine-like stems, with the vines thickly covering the ground for square miles, or even leagues, the display they make is the equal of any floral landscape to be found anywhere in the world. In the interior valleys this sand-verbena has the habit —delightful from the artist's point of view—of taking possession of a wheatfield after the grain has been reaped, where, climbing above the stubble, it changes a golden-yellow field into a pinkish-lilac flower garden. On the borders of the desert it is an early bloomer, often being at its best by March or April. It is not equally plentiful year after year, and there is a diversity of opinion as to the reason why. Some persons hold that the seed has to lie in the ground for more than one year to germinate, and that unless the rainy-season conditions are just right, most of them will hold over until a favorable season does come. But the botanist scoffs at this idea, and says that this year's crop comes from last year's seed; that a failure any year is because the plants did not seed well the year before, or because weather conditions destroyed the vitality of the seeds which were produced; that a single plant will ordinarily produce enough seed to plant an acre, if properly distributed, and that these things being so, there is no reason why the crop may not be abundant next year, although there was a scant one this season.

I rather think the botanist is right, but I'm not absolutely sure about it. I am sure, however, about the intermittent appearance of the Sand-Verbenas. In 1915, along the western border of the Colorado Desert there was perfect riot of them; in 1916, in the same region, they were almost a complete failure.

Two of the Sand-Verbenas grow almost everywhere along the beaches of the southern coast. They commence just out of reach of high tide, and extend back from the ocean as far as the wind keeps shifting the beach sand, even running up over the dunes which nearly everywhere skirt the shore. The shifting sands often cover them, but they are never so completely discouraged but that they "come back" and claim the place for their own. They play an important part in holding in place the sand deposits along the beach. Sometimes they form such a mat as to completely protect the sand deposits from the wind.

These two Sand-Verbenas and an Evening-Primrose grow indiscriminately together. So thoroughly are they mingled that it is no trick at all to gather flowers of all three at one clutch of the hand. Both of these Abronias are commonly called "Beach Verbenas." To distinguish between them we must use their botanical names, *A. maritima* and *A. umbellata*. It is easy to tell them apart for they are not at all alike, although both have the unmistakable "sand-verbena style." The *umbellata* is the prettier of the two, or at least the more agreeable, as it is less sticky and viscid, and has lighter, freer stems, as well as more open and sprightly-looking clusters of flowers. Its flowers are of a pink

Poinsettia, whose flowers are in plain sight, but rarely noticed

or rose-purple tint. The *maritima* has heavy leaves and stout, succulent stems, both very viscid and very disagreeable to handle. Its flowers are of a beautiful shade of deep magenta, surpassing in charm of tint any of the other Sand-Verbenas. The individuals are smaller than those of the *maritima*, and the clusters quite compact.

The conditions under which our Beach-Verbenas live are harsh and trying; yet they seem to thrive. And they certainly do their share in Nature's scheme of conservation.

The fourth one of California's Sand-Verbenas (*Abronia latifolia*), is yellow. It belongs to the coast of northern California, Oregon and Washington.

There are several other plant families whose flowers have to get along as best they can without corollas. Among them are the Nettle, the Buckwheat, the Goosefoot, the Amaranth, and the Pokeweed. The plants of these families are mostly classed as weeds, and there are very few flowers among them which merit our admiration. In very few cases does the calyx take on the shape and color of the missing corolla.

Some of the plants of the Buckwheat family are an exception. This is a very large family, and is perhaps most easily introduced to the unbotanical by saying that it includes the Docks and Knotweeds. We have about half-a-dozen species of each of these weeds —some native and others from abroad—and they are so common and so plentiful that nearly everybody knows them. After a certain fashion, both the Docks and the Knotweeds are rather showy, having such large spikes of closely-set flowers. In the Docks the calyx is greenish. In the Knotweeds it is green-and-pink, the pink often quite bright and quite noticeable. Both Docks and Knotweeds draw out attention when they are in seed, for the calyx persists and turns to beautiful, rich shades of brown.

But the Buckwheat Family has some real flowers— in the ornamental sense. They belong to the genera *Eriogonum* and *Chorizanthe*. Several of the Eriogonums are commonly called "Wild-Buckwheat," while the Chorizanthes are known as "Turkish-Rugging." There are numerous species of both, and only skilled botanists are equal to the task of sorting them out and calling them by name. But almost anyone may easily be able to recognize a Wild-Buckwheat, and also to know the Turkish-Rugging when one sees it. The flowers of both are small, but they have style and tint which stand close inspection. Most of them, too, occur in "mass formation," which makes them a distinctive feature of the landscape. In all cases the calyx has six sepals.

Most of our Eriogonums are shrubby, or at least have woody roots; but there are also some which are annuals. Their flowers run from white to pink, and have projecting stamens which play no small part in making them pleasing and attractive. The species which most deserves the name of "Wild-Buckwheat"—because of its resemblance to the cultivated buckwheat—

Wild Buckwheat (Eriogonum)
Its flowers are real, have style and tint

is *Eriogonum fasciculatum*. It is plentiful all over southern California, often making solid patches like a field of grain. It is not very particular about the choice of soil in which to live, and frequently is very contented in a home where no other plants seem to be willing to grow.

Chorizanthe staticoides is the Turkish-Rugging we most commonly meet with when out on the trails in our region. This is a strange-looking, low, sprawling plant that covers dry patches of the mountain side with a lace-like, pinkish-purple mat. The purple comes from the symmetrically branching stems and stiff-pointed, prickly-toothed involucres, while the pink is furnished by the sepals. You may not notice any leaves, for there are none except at the base, and they wither early. Although this flower is small, it puts up a first-class job of camouflage. When you first meet it you never suspect—unless you have been previously posted—that it has only a make-believe corolla.

It is not possible here to take up all the wild-flowers of this region which dispense with part or all of the floral dress and try to cover up the deficiency by some sort or other of camouflage. But those which I have mentioned are the most common and striking one of the sort.

Then there are quite a goodly number which are provided with both calyx and corrolla—and which are therefore scarcely justified for the act—that also resort to a certain kind of camouflage. These shall be discussed in a separate chapter.

Tower Clock Escapements*

A Review of the Development of the Escapement in Extremely Accurate Clocks

By A. T. Hare

THE most ancient instruments for measuring time were probably some kind of sundial. Something of the kind is, no doubt, referred to in 2 Kings xx. and Isaiah xxxviii., where it is stated that the shadow moved back ten steps on the steps of Ahaz (for that is the literal translation). Herodotus ("Euterpe," cix.) tells us that the Babylonians introduced to the Greeks tha πόλος and the γνώμων, no doubt some forms of sun-instruments. Frequent allusions are found in the classics to the clepsydra, which was made in various forms, always depending, however, upon the approximately uniform flow of water through a small hole.

But clocks, properly so called, cannot be traced with certainty earlier than the fourteenth century. In 1348 a curious iron clock was sent over from Switzerland, and was until recently kept in Dover Castle. It is now in the Science Museum at South Kensington. It is interesting as having no pendulum or balance-spring (both much later inventions), but, instead, a vertical spindle carrying a horizontal traverse loaded at the ends with weights. This vertical spindle has two pallets projecting from its sides, approximately at right angles to each other, which engage alternately the uppermost and lowermost tooth of a contrate wheel the axis of which is horizontal and in the same plane with the vertical axis first referred to. This is the "verge" escapement, which was for long afterwards used in both clocks and watches. No good timekeeping was possible with such an arrangement. Gravity did not come into the problem, and the speed of the movement was only restrained by its energy having alternately to create and destroy angular momentum in the swinging arms. The force of the train, however variable, was paramount.

The next step in horology, and undoubtedly the most important which has ever been made, was the application of the pendulum to clocks by the Dutch physicist and astronomer, Christian Huygens, in 1657. Galileo had discovered, about sixty years earlier, the isochronism (since found to be only approximate) of a swinging body, but, in spite of efforts made after his death to claim priority for him in the invention of the pendulum clock, the evidence has not convinced historians of his title to that honor.

Huygens, being aware of the fact that the motion of a particle under gravity was only isochronous, independently of the extent of the arc of swing, when the body describes a cycloid, and knowing the property of that curve to reproduce itself as an involute of an equal cycloid, attempted to secure the desired isochronism by suspending his pendulum from a silk thread which swung between two cheeks of brass cut to the shape of the cycloid, thus obliging the bob to trace an involute. But the silk was so affected by the weather that no good result ensued.

Another objection to the verge escapement was the large arc of swing necessary to permit the escapement to unlock itself. Huygens attempted to overcome this difficulty by making the verge the axis, not of the pendulum-crutch, but of a pinion gearing into a larger wheel to the arbor of which the crutch was attached. This construction permitted the angle of swing to be reduced at pleasure, but more friction was introduced, and little improvement was effected.

The calculation of the time of swing of a free pendulum describing a circular arc can only be made approximately, but the approximation can be carried as far as desired, and as the arc of swing is never large, a few terms suffice. This is the formula:

$$T = \frac{\pi k}{2\sqrt{gh}}\left(1+\frac{1}{4}\sin^2\frac{\alpha}{2}+\frac{9}{64}\sin^4\frac{\alpha}{2}+\ldots\right)$$

from which, by differentiation,

$$\frac{dT}{d\alpha} = \frac{\pi k \sin\alpha}{16\sqrt{gh}}\left(1+18\sin^2\frac{\alpha}{2}+\ldots\right).$$

Here T is the time of swing of the pendulum from its highest position to the vertical, and α is the semi-angle—that is, the angle turned through from the highest to the lowest position. Now of the factors making up the expressions on the right-hand side of these equations, only π and g and the numerical coefficients can really be considered as constant. It has been suggested that even g may one day be shown to be variable. As for h and k—that is, the distance from the axis of motion to the center of gravity and the radius of gyration respectively—these are well known to be dependent on temperature, and an interesting account might be given, if time permitted, of the evolution of the compensated pendulum. The recent discovery of alloys of iron and nickel the coefficient of expansion of which is very low has much facilitated this.

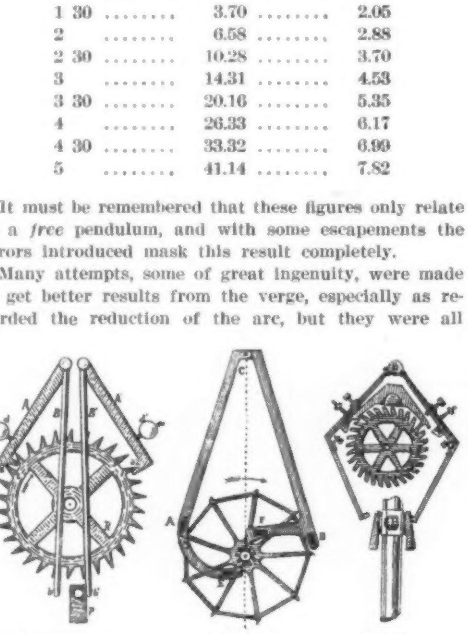
The factor which has most influence on the value of T is α, the angle of swing. The formulæ show us two things; first, that the wider the arc of swing the more a clock will lose, and, secondly, that a given small variation of arc is less harmful when the whole arc is small than when it is great. There are practical reasons, however, for not making it *too* small, which have led to the adoption of arcs of two or three degrees on each side of the vertical as, on the whole, the best.

This table gives the losing rate for variations of arc.

Semi-arc ° ′	Daily loss sec.	Difference sec.
0	0	
0 15	0.1	0.1
0 30	0.41	0.31
1	1.65	1.24
1 30	3.70	2.05
2	6.58	2.88
2 30	10.28	3.70
3	14.31	4.53
3 30	20.16	5.35
4	26.33	6.17
4 30	33.32	6.99
5	41.14	7.82

It must be remembered that these figures only relate to a *free* pendulum, and with some escapements the errors introduced mask this result completely.

Many attempts, some of great ingenuity, were made to get better results from the verge, especially as regarded the reduction of the arc, but they were all superseded by the anchor, or recoil, escapement, invented (most probably) by the celebrated Dr. Hooke, and first made by William Clement in 1675. This is the escapement still used in all common clocks, but it has disadvantages which render it unsuitable for high-class work. The train exercises great "dominion," as it used to be called, over the pendulum, and is assisting gravity the whole time, hindering the rise of the pendulum and accelerating its fall, so that T may be considerably diminished when the train has been recently oiled without any corresponding variation of α.



Mudge's Bloxam's Kater's

Gravity escapements for tower clocks

But in 1715 George Graham, pupil of Tompion (both of whom were so esteemed as to be accorded burial in Westminster Abbey), made a most important modification of the anchor. He removed most of the flukes, leaving only a small sloping part near the tip, by sliding along which the extremity of the scape-wheel teeth could give the necessary impulse to the pendulum. The rest of the fluke he fashioned so that it should be a portion of a circle having its center on the axis of the crutch-arbor, thus entirely preventing recoil of the movement, and, to a great extent, releasing the pendulum from the "dominion" of the train. During the time when the circular part of the fluke is passing along the tooth of the scape-wheel the motion of the train is entirely held up, and it is neither doing work on the pendulum nor having work done on it. The device is consequently known as the "dead-beat."

Numbers of escapements were devised after Graham's invention, which, though differing much from it in design, were, nevertheless, broadly speaking, mechanical equivalents of it. Such were Thiout's, Vérité's, Perron's, Leonhard's, Vulliamy's, Robert's, Berthoud's, Lepauté's, and Brocot's.

The designer of a turret-clock, however, always has in mind the serious variations in the force of the train caused by wind or snow on the hands, as well as by the thickening and drying of the oil on the bearings and the cutting and wearing of the pivots and of the teeth of the wheels and pinions. It was, therefore, long ago recognized that the proper function of the clock-train was not to drive the pendulum, but to record the number of its swings—that is to tell the time—and to keep wound a smaller clock which should be independent of these disturbances, and could be made very simple, and even reduced to one wheel, if often enough rewound. This construction was proposed by Huygens, who did so much for the science of accurate timekeeping. The principle of these "remontoirs," as they are called, is very much the same in all. Some rewind a little weight, others keep a spring wound, but in every case, directly or indirectly, the pendulum has to unlock the rewinding mechanism by means of some device which is itself an escapement, and this cannot be effected without some friction.

From the train-remontoir it is an easy step to the next great improvement. The question naturally arises: "Why rewind the train in the middle? Why not simply relift the pallets and let them fall by gravity on the pendulum?" This question was answered about the year 1716, when Alexander Cumming produced the first of the series of gravity escapements which have done so much to make the accurate turret-clock a possibility. His escapement is rather complicated and has several points where there is friction, and very soon after it was greatly simplified and improved by Thomas Mudge, a pupil of Graham's. Fig. 1 shows Mudge's escapement, and will be easily understood.

The tooth marked 1 has just lifted the gravity piece A′B′, and is resting on the dead face. The pendulum, moving to the right, is just about to lift the gravity piece, causing the dead face to slide along the tooth until it is clear of it. The wheel is then free to turn further, and the tooth marked 2 lifts the other gravity piece AB in a similar way. When the pendulum has attained its maximum elongation to the right (carrying A′B′ with it) and begins to return, the pallet on A′B′ falls midway between teeth 1 and 3, thus falling rather farther than it rose, the balance of work done on the pendulum serving to maintain the latter in motion against the resistances. Each gravity piece is lifted by the wheel at a time when the pendulum is out of contact with it, and so the action of the train cannot disturb the pendulum except by the friction of the dead faces.

There is, however, a source of error to which Mudge's escapement is liable which was sufficient to condemn it. The driving power had to be ample, and there was danger either that the gravity pieces might be thrown clean off the wheel, allowing the latter to race and destroying all timekeeping, or that, if this complete "tripping" did not occur, they might, at all events, be thrown a little too high, so that the teeth of the scape-wheel, instead of resting in the exact corner, as tooth 1 is seen to be doing, would rest on the dead face nearer its extremity, and probably hold up the gravity piece, by friction, higher than it should. This fault was called by Lord Grimthorpe "approximate tripping," and if it occurred the constancy of the maintenance would be lost. This might probably have been cured by the use of a dashpot with which Mudge's escapement would have been very considerably improved.

Mudge's escapement was followed by Bloxam's, the action of which will be obvious from Fig. 2. It is still to be seen in action in Bloxam's own clock, which is now, by his nephew's permission, at the Science Museum. The noteworthy feature in it is that the locking arms are much longer than the lifting teeth, so that the friction of unlocking is much reduced.

It was on Bloxam's design that Lord Grimthorpe improved in the construction of his well-known "double three legged gravity escapement," used for the first time in the great clock in the Houses of Parliament. The principal feature in this escapement is the long wind-fly, which moderates the shock of impact of the teeth on the pallets, and which the large angular movement of the scape-wheel (60° at each tick as against 20° in Bloxam's) rendered effective.

A new principle was introduced into the gravity escapement by Capt. Kater about the year 1840, and is

*From a lecture delivered at the Royal Institution; reprinted from *Nature* (London).

described in vol. cxxx. of the Phil. Trans. Fig. 3 is taken from Kater's paper, and shows clearly the design. The gravity pieces are lifted alternately as in Mudge's and Bloxam's constructions, but they do not themselves unlock the escapement, merely serving to upset the equilibrium of a heavy piece (seen in the figure above the wheel), which does the unlocking, but, owing to its high moment of inertia, gets slowly under way and so unlocks the wheel only when the gravity piece then in contact with the pendulum is no longer touching it.

Vérité produced a gravity escapement in which pivot friction was got rid of, but this escapement had four little balls hanging from four silk threads, and was somewhat delicate and complicated.

It occurred to me some time ago that Kater's principle might be applied in such a way that the pendulum should be entirely freed from all friction whatever, while the impulses given to the pendulum were exactly uniform. A full description of this escapement will be found in Patent Office Specification No. 113,501, but it may be said, very briefly, to consist in two little weights which rest alternately on the two ends of a rocking frame having considerable moment of inertia, and on two little upright stems at the ends of arms fastened to the pendulum near its point of support. When the rocker is horizontal, and the pendulum at rest and vertical, things are so adjusted that the weights are resting indifferently on both the pendulum arms and the ends of the rocker. If, then, the pendulum is pushed to one side, say the right, it carries the right-hand little weight upwards, relieving the rocker of its weight, and deposits on the opposite end of the rocker the other little weight. This upsets the equilibrium of the rocker, which commences to turn over, and so releases the scape-wheel, which turns the rocker back rather beyond the horizontal in the sense opposite to that of its last motion, so that when on its return the pendulum again exchanges weights with the rocker, it deposits the right-hand weight at a lower level than that at which it was picked up. The escapement is simple, and a clock fitted with it has given results which are encouraging.

Before concluding, I must refer to a remarkable series of papers which commenced last year to appear in the Proceedings of the Royal Society of Edinburgh by Prof. R. A. Sampson, the Astronomer Royal for Scotland. Prof. Sampson is, as all astronomers must be, much interested in accurate timekeeping, and has experimented with three different clocks, having escapements which I must very briefly describe. One is by Mr. Cottingham, and is essentially the same as an escapement which the late Sir David Gill, then Astronomer Royal at the Cape, had imagined. The pendulum is driven by a gravity piece which, so long as it is in contact with the pendulum, by that very contact completes an electric circuit which holds up an armature against the poles of an electromagnet. This armature is itself the stop which limits the travel of the gravity piece. The latter, therefore, goes on impelling the pendulum until it is brought up against the armature. When this happens the gravity piece is left behind by the pendulum and the circuit is broken. At once the armature falls against a stop, and the gravity piece is lifted, so that the pendulum takes it up again at a higher level than that at which they parted company. Sir David Gill found trouble from the slight adhesion which exists between two metallic surfaces when a current is broken between them, and gave much attention to experiments designed to avoid this. I do not know how far he succeeded, but it seems clear from Prof. Sampson's paper that the escapement is very successful now. The idea has probably occurred to many people. I began making a clock about thirty years ago on what was practically the same principle, but gave it up because at that time it did not seem practicable to find a battery capable of giving a current lasting nearly half a second for each second that passes.

Another of Prof. Sampson's clocks is driven by an escapement invented by Riefler, of Munich, which is unlike any of those we have been considering, and in which the necessary energy is communicated to the pendulum by bending the suspension spring. The block from which the suspension spring hangs, instead of being fixed as immovably as possible, which it generally is, is supported on knife-edges, and the suspension spring, which, of course, always tries to keep straight, causes the block to turn on these edges, and so unlock the scape-wheel, which bends the spring back against the motion of the pendulum and thus keeps it going.

The third escapement which is being observed at Edinburgh, and the last I purpose to refer to, belongs to the class where the action takes place at the bottom of the pendulum or of the crutch instead of the top. This is fully described in the specification of a patent granted to Mr. Shortt, and numbered 9527 of 1915.

So much for escapements.

We may, in conclusion, for a moment review the difficulties attending the accurate measurement of time and note how they have been attacked.

If ever a perfect clock is constructed it will certainly be a pendulum clock, and it will have to fulfil two conditions, necessary and sufficient. They are these: First, the moment of inertia of the pendulum must be invariable; and, secondly, the forces which act on it must be inavarible. If these two conditions could be fulfilled, the last word in horology would have been said. So far, of course, neither condition has been fulfilled, but surprisingly good work has been done. As for the first condition, that the moment of inertia must be invariable, the chief difficulty is to avoid change by change of temperature. There are two ways of diminishing this change. The pendulum must be compensated in one of the well-known ways—by Harrison's gridiron construction; or that of Graham by the expansion of mercury in the bob; or, again, by the zinc and iron combination used in many turret-clocks; or, best of all, by availing ourselves of the low expansion nickel-steel recently introduced by Guillaume. Also, for added security, the whole clock must be enclosed in a thermostatic chamber, as is done by Prof. Sampson at the Royal Observatory at Edinburgh. The other condition is much more difficult. There is, besides the almost inevitable friction of the escapement, the effect of the buoyancy of the air. This last can be avoided by enclosing the whole clock in a glass case, tightly fitted, in which the air can be slightly rarefied and maintained at a constant pressure below that of the atmosphere. This would seem to offer a very satisfactory solution of the difficulty. Temperature error and buoyancy error having thus been to a great extent mastered, we come back to the forces connected with the maintenance and recording of the motion as the principal sources of uncertainty. And let no one suppose that little has been effected. Perfection in this, as in other human pursuits, is doubtless unattainable, but we approach it asymptotically, and we are farther along the asymptote than might be imagined. Prof. Sampson tells us that in his thermostatic chamber and barostatic cases, and with the Riefler, Cottingham, and Synchronome escapements which he is studying, the errors average no more than one-hundredth of a second per day—that is, at the rate of one minute in sixteen years, if the clock could run so long without stopping—truly an almost miraculous accuracy, unrivalled, I imagine, in any physical measurement. Anyone, therefore, who hopes to improve upon this has a difficult task before him. If it is true that *le mieux est l'ennemi du bien*, it must be acknowledged that *le mieux* has against him a most formidable antagonist.

The Physiological Sensations Produced by Detonations

Violent noises such as those caused by thunder, severe explosions, the firing of big guns, and the aerial "wake" of projectiles travelling at high speed produce upon the ear special sensations which are very different from those occasioned by ordinary sounds and noises, even when the latter are extremely intense; there is in particular a failure to receive the impression of musical *height*. The question as to the nature of this difference is naturally of peculiar interest at the present time and has recently been studied extensively by a French scientist, M. Ernest Esclangon, who has just reported the results of his investigations to the French Academy of Sciences.

The internal ear is composed as we know of a large number of independent organs. Among these are the fibres of Corti, which are comparable to resonators, and which vibrate individually when the sound perceived comprises the corresponding components.

Certain physiologists are of the opinion that the basilar membrane plays an important part in the matter. It is supposed to be stimulated by sounds, but in a manner which differs according to their composition; the theory is that a sort of system of nodal lines is produced in it variable according to circumstances and harmonizing with the sound we receive in such a manner that no component within the limits of our powers of hearing can escape being perceived and analyzed. Whatever may be the intimate mechanism of auditory intricacies we are forced to believe that the perception of ordinary sound is apparently due to an ensemble of phenomena relating to internal resonance, the *quality*, i. e., the height and timbre of the sound, being obtained by means of cerebral analysis.

Since the constitution of the middle ear fits it to act as a sort of manometric chamber it is this portion of the ear which is peculiarly sensitive to effects produced by pressure. In a vibrating atmosphere which exhibits no manometric variation it fails to be impressed.

Let us imagine that in an atmosphere which is in repose in the beginning there occurs a short but very sudden variation of pressure, a sort of manometric *percussion*, measured by a thousandth, a hundredth, or a tenth or more, of a millimeter of a column of mercury.

We are no longer concerned with any question of phenomena relating to internal resonance, since such a disturbance could comprise neither a definite period nor a definite duration. But if the manometric variation is sufficiently rapid the entire organ will be jarred like the keys of a piano which are struck simultaneously. The sensation perceived in this case would be precisely like that of a detonation and the more sudden and powerful the manometric percussion the keener the sensation. It is readily conceivable that under such conditions no height of musical tone could be associated with the impression received.

M. Esclangon makes use of a single experiment in support of the conclusions stated above. This consists of the introduction of one end of a rubber tube into the ear; if the other end be tightly squeezed between the fingers and suddenly released the auditory impression is precisely like that of a detonation; if one breathes gently into the free end of the tube an excellent imitation of the sound of thunder will be produced. The investigator offers the following explanation of these phenomena: the sensations of detonation appear to be connected with waves of discontinuity of pressure in fluids—discontinuities, furthermore, which are always physically speaking more or less absolute. But explosions, i. e. the sudden expansion of gases, either when they are violently compressed or when they result from the combustion of an explosive, give rise to waves whose forward portion manifests itself by a sudden access of pressure. In the same way the aerial wake of a projectile travelling with a speed greater than that of sound possesses a front which comprises an important and rapid variation of pressure. It results from this that when the edges of this wake or furrow in the air encounter the ear of an observer the latter inevitably experiences the same effect as in the case of a violent detonation. In this simple manner we may explain the origin of purely ballistic detonations, i. e. those due to a single movement of projectiles through the air. The acoustic effects of thunder can be explained in a similar manner.

How to Study Steel

(*Continued from pgae 3.*)

uniform pressure depresses the change-point which would have resulted in an increase of volume, and raises it if it would have resulted in a decrease in volume. The importance of this in the quenching of steel is pointed out.

5. Non-uniform pressure always depresses the melting-point. An actual fusion of a small portion of a metallic mass undergoing plastic deformation is assumed, and the authorities quoted, and shown to be capable of explaining the known facts.

A SHORT BIBLIOGRAPHY.

The following brief list of works relating to the problems discussed in the paper is obviously not exhaustive, but it will serve as an introduction to the study of the solid and liquid states of matter for those interested in the subject:

Poynting and Thomson. Properties of Matter. Charles Griffin and Co., Limited, London. (The best introduction to the subject.)

Johnson and Adams. Am. Jour. Sci., March, 1913, v. 35, p. 205-253. (An important discussion of the effect of high pressure on the physical and chemical behavior of solids, with very complete references.)

Johnson and Adams. Am. Jour. Sci., June, 1911, v. 31, p. 501-517. (Describes experimental work on the effect of pressure on the melting-point of metals.

Wheeler. Am. Jour. Sci., August, 1911, v. 32, p. 85-100. (Discusses the reflection of light at metal-liquid surfaces.)

Willows and Hatschek. Surface Tension and Surface Energy. J. and A. Churchill, London. (A useful introduction to the study of surface tension.)

Day, Sosman and Hostetter. Am. Jour. Sci., June, 1914, v. 38, p. 1-39. (Discusses volume changes of solids with variations of temperature, and makes an important revision of the classic work of Carl Barus on the volume of solid and liquid diabase.)

Connecting up a receiving set is no mean wiring job, even if this is called wireless telegraphy

These cardboard tubes, wound with numerous turns of wire, are called loading coils, and serve to build up wavelength

Experimental Wireless Telegraphy and Telephony—I*

Elementary Principles Regarding Apparatus and Means Employed in Radio Telegraphy and Telephony

By Louis Gerard Pacent and Austin C. Lescarboura

As in most other fields of applied electricity, one cannot delve deeply into radio communication without encountering formidable mathematical calculations. Indeed, it is the presence of intricate formulæ in many works on the subject that has caused laymen to turn away in dispair; yet, as a matter of cold fact, it is possible to experiment in the field of radio communication without troubling one's self with the mathematics thereof. It resolves itself down to a matter of interesting one's self in the practical use of the apparatus with little regard to the theory, particularly such theory as requires the extensive use of mathematics to explain a bit of action or to measure currents or waves.

Because of the lack of space and because the scientific world is already overtaxed with works on elementary principles of electricity and magnetism, the authors have omitted going into the details of fundamental electricity and magnetism. It is taken for granted that the reader is acquainted with the simple electrical terms and theories which will be referred to; and if he is not so acquainted, it is taken for granted that he will gather the necessary basic information from the numerous works available.

It is with the object of guiding the layman through the various phases of radio communication that the authors have prepared this work. In so far as is practicable, they have endeavored to eliminate mathematical formulæ, working on the idea that in this instance the layman wishes to purchase and operate apparatus for the purpose of receiving and transmitting messages and for experimental purposes. That is to say, the layman here is considered in the same light as the man purchasing an automobile: he is interested in the pleasure the equipment will furnish him, primarily; and he is somewhat interested in how his automobile functions, because that enables him to get the most service out of it. But when it comes to analyzing the formulæ and curves and abstruse theories of automobile engineering, he prefers to leave that side of motoring to the automobile engineer.

While limiting themselves to a simplified explanation of radio communication and radio apparatus, the authors have made every effort to incorporate the latest ideas in this work. The war has resulted in many radical departures in radio communication; so much so, in fact, that wireless telegraph and telephone equipment is now broadly classified as pre-war and post-war types. And reflecting the developments brought about in naval and military equipment, the amateur instruments likewise have been changed to no little extent.

Among the new developments now available to the wireless amateur and which will be covered in subsequent chapters of this series are:

(*a*) Radio telephony using vacuum tubes for the generation of undamped high-frequency oscillations.
(*b*) Barrage receiver for duplex radio operation and for the elimination of interference and static or strays (atmospheric electricity).
(*c*) Weagant's system for the elimination of strays.
(*d*) Loop receivers, which possess remarkable characteristics such as direction-finding.
(*e*) Loop transmitters.
(*f*) Underground systems of long-distance reception.
(*g*) Direction-finders of various types.
(*h*) Various ways of modulating the high-frequency systems for radio telephony.

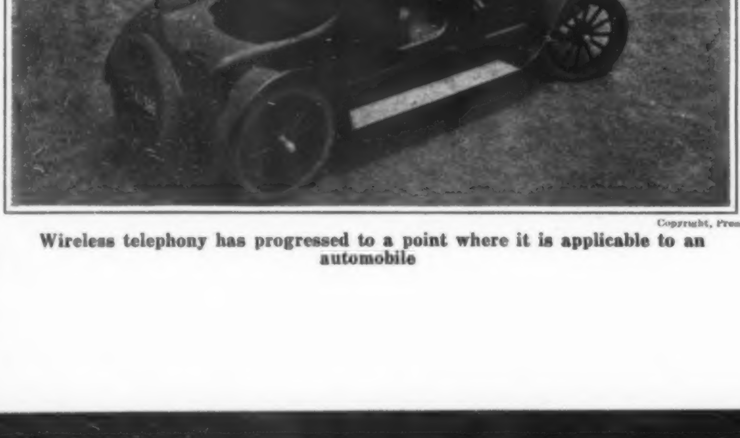
ELECTROMAGNETIC WAVES THAT TRAVEL THROUGH SPACE.

When a pebble is thrown into the smooth water of a pond it starts a series of concentric ripples or waves, which spread out indefinitely with a speed of a few hundreds of a meter per second. Similarly, an electrical disturbance caused by a wireless transmitter starts electric waves, which spread out in all directions. These waves affect receiving stations at distant points, and that, in brief, explains the principle of radio communication.

Now the pool in which wireless waves are created and propagated is the ether. It is a well-known fact among scientists that all space and matter contain ether—a medium for the conduction of electro-magnetic waves. Although the ether, which is not to be confounded with the ether employed by surgeons, is invisible, odoriess, and otherwise does not indicate its presence by the usual means, it is claimed to be as essential to our existence as the air which we breathe. Scientists tell us that the universe is one vast ocean of ether.

So it follows that the function of a wireless transmitter is to set up waves in the ocean of ether, just as the stone thrown in the pool creates ever-spreading waves. The waves in radio communication, which travel at the rate of 186,000 miles per second, are created by the discharge of a condenser of some type or other across a spark gap through a self-inductance coil, and this simple circuit in which the periodic discharges occur is connected either directly or indirectly to the antenna system and ground. The antenna and ground serve to propagate the waves into the ether at the transmitting end, and detect the waves at the receiving end. The antenna and ground may be looked upon as a hinged paddle dipping in the pool of still water already referred to. If this paddle is worked back and forth, the power exerted is converted into

*This article is the first of a series by these authors. The entire series will cover every phase of the amateur radio art not only serving as a handy guide to the installation and operation of amateur apparatus, but as a stepping stone to commercial practice. (Copyright, Scientific American Publishing Co., 1919.)



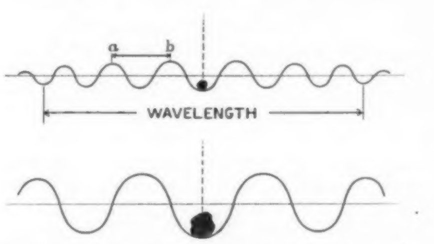
Wireless telephony has progressed to a point where it is applicable to an automobile

The wireless telephone enables the motorist to keep in touch with his home station

waves which travel in all directions through the pool. Now if another similar paddle is placed some distance away, it will begin oscillating as the waves from the first paddle reach it. These oscillations, in turn, can be made to strike a bell, run a pencil back and forth across a sheet of paper, or otherwise indicate that the paddle is being affected by surface waves. All of which is precisely what aerials and grounds do in radio communication. The aerial and ground go together, it being necessary to employ elevated wires for the aerial, as well as some form of connection or relation with the earth to complete the electrical arrangement, except in special instances which will be covered later on.

Everyone who has studied electricity in even an elementary way is familiar with the discharge of a condenser, such as a Leyden jar, charged by any one of several methods available. The discharge across the spark gap appears as a single spark, but in reality it is composed of a great many sparks following each other in rapid succession. Indeed, the condenser discharges its accumulated energy first by a tremendous rush of current across the gap in one direction, and then another discharge somewhat less powerful in the opposite direction, and still another discharge in the first direction, and so on, back and forth, just like the action of a pendulum, with each discharge weaker than the preceding one until the condenser is completely discharged or emptied of its original accumulated charge. Yet the complete series of discharges takes place in an almost immeasurable fraction of time, depending on what is termed the oscillating or radio frequency. And it is the rapidity of discharge that causes the creation of high-frequency alternating currents, as compared with the very low frequency currents used for power and lighting purposes.

The value of this oscillating or radio frequency depends on the measure of the propagated waves. The term wavelength is employed in giving the value of



The analogy of small and large stones dropped in water, showing the formation of waves of varying power

radio waves. The wavelength is the result of the oscillating frequency; oscillating or radio frequency, in turn, is the result of the capacity and inductance values in the oscillating circuit. As in alternating current practice, one complete reversal in the spark discharge, that is to say, one discharge in one direction and another discharge in the opposite direction, constitutes what is known as a cycle. Various standard wavelengths are herewith given, together with their equivalent frequencies:

200	meters	1,500,000	cycles per second
300	"	1,000,000	" " "
600	"	500,000	" " "
1,000	"	300,000	" " "
1,500	"	200,000	" " "
3,000	"	100,000	" " "
5,000	"	60,000	" " "
10,000	"	30,000	" " "

Under the prevailing wireless laws in the United States the wireless amateur station is limited to a wavelength of 200 meters for the transmitter except in special cases. Ship-station transmitters operate on a wavelength of 300 or 600 meters, while Government and long-range stations operate on longer wavelengths. Wavelengths above 18,000 meters are never employed except in experimental work, because the frequency then becomes too low to be practical while the aerial system has to be of such vast proportions and the power necessary to charge it must perforce be great.

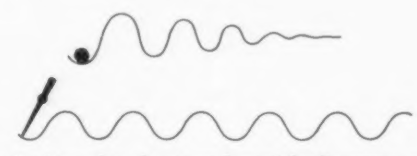
In order to make use of radio waves for the practical purpose of sending messages and then receiving them at a distant point, it is necessary:

(*a*) To produce regular electrical disturbances in a circuit which starts the waves. (These disturbances are electric currents which reverse rapidly in direction, as already outlined).

(*b*) To get the waves out into surrounding space, through which they travel with great speed. (This is done by means of the transmitting antenna.)

(*c*) By means of these waves, to set up electric currents in a receiving circuit at a distant station. (The device which these waves strike as they come in, and which turns them over to the receiving circuit, is called the receiving antenna or aerial.)

(*d*) To change these currents so that they may be detected by electric instruments. (The operator usually receives the message through signals in a telephone receiver.)



Analogy for damp and sustained waves as produced in water by a stone and a paddle

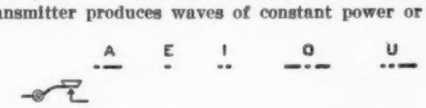
METHODS OF PROPAGATING RADIO WAVES AND INTERCEPTING THEM.

Taking up first the methods of producing electrical disturbances, it may be said that there are numerous arrangements now available even to the amateur as compared with one or two in the early days of the art. Formerly the amateur produced the wireless waves by the simplest means, namely, a spark coil or transformer, a condenser, a simple inductance, and a spark gap of plain design. The spark coil or transformer served to charge the condenser, which in turn discharged through an inductance and across a spark gap, thus creating oscillations, which were transferred either directly or indirectly to the aerial system.

Today the amateur has a wide choice of transmitting apparatus. Aside from spark coils and transformers, which may be used with improved forms of gaps, such as quenched and rotary gaps which will be described further on, he can make use of simple vacuum tubes which generate radio waves for telegraph and telephone purposes. Indeed, the vacuum tubes, as we shall read later on, have more or less revolutionized radio communication. Then there is the arc generator, which is little more than a carbon arc connected in circuit with condenser, inductance, and other accessories. The arc generates currents suitable for either wireless telegraphy or telephony. Again, there is the high-frequency alternator, which is a modified form of alternating-current generator capable of producing currents of high frequency, which in turn can be used for creating waves.

The circuit in which the electrical disturbances or oscillations are produced is known as the oscillating circuit. This circuit is connected or coupled to the antenna or aeral circuit in such a manner as to transfer the disturbances or oscillations to the aerial circuit. If the coupling between the two circuits is close in the electrical sense, it is known as a close-coupling, and the set is said to be closely-coupled; whereas if it is loose, still speaking in the electrical sense, the coupling is said to be loose-coupling, and the set is loose-coupled. The relative effects in close-coupled and loose-coupled arrangements will be dealt with later. These arrangements are also employed in receiving.

Transmitters generate one of two kinds of waves, known as undamped or continuous waves, and damped waves. The undamped waves, as will be noted by studying one of the accompanying sketches, can be compared with a simple water analogy. If a paddle is kept moving, it produces steady waves all of about the same peak. In wireless, the effect is the same; the transmitter produces waves of constant power or am-



This diagram shows how the wireless telegraph and the wireless telephone transmit the vowels

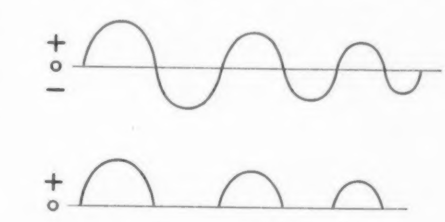
plitude. In damped waves, on the other hand, the best analogy is that of a pendulum. The pendulum receives an impulse every so often, and sets swinging with big strokes at first but with each stroke shorter than the preceding one. If the impulses are applied at long intervals, the pendulum stops in between. So in wireless, a damped wave is one in which the impulse is applied every so often, and the cycles soon die down, as shown in one of the accompanying sketches. A group of these cycles caused by a single impulse is known as a train. Every time the transmitting key is pressed, a large number of trains are sent out through space, and at the distant receiving station it is the trains which set up the audible indications or buzzes in the operator's receivers. Damped waves may be either moderately damped or highly damped, depending upon the spark gap and other features of the transmitter.

Wireless telegraphy and telephony differ in that one makes use of a telegraph code of dots and dashes, while the other uses the voice. In the case of the first, the generated waves are merely interrupted to form the dots and dashes, by means of a telegraph key. In the second the waves, which must be of the undamped variety, are sent out continuously, but the power or amplitude of the continuous train of waves is altered, in the manner shown in one of the sketches.

Now then, the aerial or antenna circuit comes up next for consideration. As already mentioned, the aerial circuit consists of the aerial proper, and a ground or earth connection in most instances, although there are systems of aerials where no ground is employed. The aerial proper consists of a number of insulated wires, either elevated some distance or lying close to the ground or even buried. The elevated aerial may be arranged in several ways; for instance, it may consist of one long wire running between a tall house and a low house, with the connection taken off the lower end. Again, it may consist of a number of wires between masts and poles, as on shipboard. Still another arrangement is known as the umbrella aerial, in which one pole is used as the center, with the wires radiating in all directions and terminating in short poles at their lower end.

ODDITIES IN AERIAL SYSTEMS.

And in these days of advanced practice, an aerial need not necessarily be an aerial, in the accepted sense



Received wireless wave and how a detector rectifies it for the telephone receiver worn by the operator

of the word. It may be a buried wire, such as has been used during the war for long-distance reception. It may be a loop of many turns of wire about three or four feet in diameter for amateur purposes, and larger for commercial work, known as a loop receiver or transmitter and used indoors or outdoors, as may be most convenient. Again, it may be the conventional telephone line, tapped through a small condenser so as not to interfere with the electrical system of the service. It may be a large metal object or collection of objects, such as a metal bedstead, a fire-escape, a large stope-pipe or metal chimney, and so on; for, after all, the aerial is merely an insulated mass which serves to intercept the radio waves as they spread out in all directions from the transmitter, and to lead them through the receiving set down to the earth connection.

One more word about the loop antenna. This form has a decided advantage over the usual high elevated antenna system, because of the fact that, being only exposed electromagnetically and not electrostatically—no ground connection being used—it is affected but little by atmospheric electricity which gives rise to the troublesome interference known as "static." At times the static noises are so loud and so persistent in the receiving apparatus that it is impossible to hear and "read" signals from a transmitting station. That is why, in the past, long-distance stations have often been unable to transact their business for hours at a time. In short, static has been the curse of the radio engineer. Of cource, with a loop antenna the signals are weaker than they would be with a large aerial system, and must be amplified for proper audibility in many instances.

Direction-finding is another advantage of the loop antenna. As will be described in that part of this work dealing with aerial systems, the loop receives signals loudest when it is properly adjusted to receive them from one particular direction. This feature of the loop makes for no end of interesting experiments.

(*Continued on page* 16)

Acquired Radio-Activity*

Forty Years' Experiments with X-Rays, Cathode Rays, and Radium on Various Minerals

By Sir William Crookes, O.M., LL.D., D.Sc., &c.

EXPERIMENTS WITH CATHODE RAYS

1. About forty years ago I sealed in a vacuum tube a yellow diamond cut as a brilliant. This diamond was chosen because it phosphoresced in the dark after exposure to bright sunshine—it also phosphoresced slightly under the influence of ultra-violet light. In the vacuum tube, as the anti-cathode, it emitted a brilliant yellowish white light giving almost as much light as a candle. It was often exhibited to illustrate the glow of a diamond under the influence of cathodic rays *in vacuo;* scarcely a week passed without the vacuum tube containing the diamond being exhibited to friends. It was by far the most attractive tube in my collection. After forty years of hard work the diamond has become much discolored. It was of interest to see if the repeated bombardment, as the anti-cathode, in the vacuum tube had conferred radio-activity on the diamond. Accordingly I opened the tube, quickly removed the diamond, and in the dark put it on a sensitive film, a thin sheet of black paper intervening. Over the diamond was placed a pad of cotton-wool and a weight, to prevent the stone from shifting its position. After nine days' contact the film was developed. An exceedingly slight action could, with difficulty, be detected, showing that the off and on action for forty years had conferred practically no radio-activity on the diamond.

2. A sensitive electroscope was now made, with sulphur insulation. The fall of the leaf was observed with a small telescope having a photographed scale. The normal fall due to natural leakage was 5° in 165 seconds. A piece of a thoria gas mantle caused a fall of 5° in two seconds, and radio-active diamonds caused a fall in from two or three seconds to a fraction of a second. Tested in this instrument I found this special diamond to be entirely devoid of action.

ACTION OF CATHODE RAYS ON DIAMOND.

3. On one occasion when M. Moissan was in my laboratory I darkened some diamonds by means of cathode rays. One of these he took away, and subsequently reported the result of his experiments to the French Academy (*Comptes Rendus*, cxxiv., No. 13, p. 653, March, 1897). He heated the diamond to 60° C. in an oxidizing mixture of potassium chlorate and fuming nitric acid, prepared from monohydrated sulphuric acid and potassium chlorate fused and free from moisture (9, 12, 32). The action on the dark layer is very slow, requiring at least eight or ten days for its complete removal. There is at first produced graphitic oxide which at an increased temperature yields pyrographitic acid easily destroyed by nitric acid. Hence the variety of carbon which coated the diamond is graphite. The transformation of diamond into graphite requires the temperature of the electric arc, and the higher the temperature at which it is formed the greater is its resistance to oxidation. M. Moissan came to the conclusion that the temperature reached by the surface of the diamond blackened in my radiant matter tube was probably about 3,600° C.

4. Six diamonds—having different degrees of phosphorescence under cathode rays—were tested in a Becquerel phosphoroscope to see if the order of intensity of the residual phosphorescence due to illumination with an arc light was the same as the order under cathode rays. All had a slight residual phosphorescence, but the order of intensity differed in the two cases.

ACTION OF CATHODE RAYS ON VARIOUS MINERAL SUBSTANCES.

5. For many years I have experimented on the changes produced in ordinary and quartz glass and various crystals by exposure to radium emanations and rays.

Considering the identity of the cathode discharge in a high vacuum tube with the β rays from radium, experiments were started to ascertain if the cathode rays would confer radio-activity in various solid bodies submitted to its influence. A vacuum tube was prepared with a removable window at one end to allow the contents to be exchanged for other bodies. In the tube were placed pieces of uranium glass, a crystal of ruby, a crystal of garnet, a piece of quartz, a plate of platinum and one of gold. The tube was exhausted to a high vacuum just short of the non-conducting point. On excitation the whole tube was filled with the green glow of phosphorescent glass, the ruby and uranium glass became very phosphorescent, the other bodies remained quite dark. After an hour's exposure to the cathode discharge the tube was opened, the objects quickly removed in the dark and placed on a sensitive film; the upper sides that had received most bombardment being placed downwards on the film. They were kept thus for eighteen hours and the film then developed. There was absolutely no impression of any of the bodies on the film. Thus it appears that the cathode stream will not confer radio-activity on the above-named bodies.

ACTION OF CATHODE RAYS ON PHOSPHORESCENT BODIES.

6. Experiments were next tried to see if earths and compounds which became strongly phosphorescent under the influence of the cathode discharge would thereby become radio-active. Some ignited yttrium sulphate, in the condition most sensitive to the cathode rays and giving under their action a phosphorescent glow with a discontinuous spectrum, was pressed tightly into a shallow aluminum tray and exposed for an hour to the discharge in the vacuum tube. It was then removed and immediately covered with a sensitive film pressed down with a slight weight. After forty-eight hours in total darkness the film was developed. Only a very slight image of the yttria was visible. This result does not prove that the cathode stream had rendered the yttria radio-active, for there is always a residual glow in the yttria in these circumstances; it is not unlikely that the light of this glow, acting for the first hour or so of the forty-eight, might have been strong enough to impress the film (7).

7. Three shallow trays were filled—one with phosphorescent calcium sulphide, another with zinc sulphide, and a third with platinocyanide of barium. After subjecting them to the cathode stream in the above manner, they were removed and covered with a sensitive film, and kept in darkness for twenty-four hours. On development only an impression of the zinc sulphide was seen. As this sulphide also has a certain amount of residual glow after exposure to the cathode rays it is probable that the photographic action is only the result of this glow (6).

ACTION OF RADIUM ON DIAMOND.

In June, 1904 (*Roy. Soc. Proc.* lxxiv., 47), I read a paper before the Royal Society on the action of Radium on Diamond.

8. A few years later I repeated the original experiment, exposing two New South Wales diamonds to the action of the radium rays and emanations for a longer period. The diamonds selected were of an identical pale yellow, devoid of radio-activity. A quartz tube containing 15 mgrms. of pure radium bromide was well exhausted and sealed before the oxyhydrogen blowpipe. One of the diamonds was put close to the tube of radium and kept in its place with a piece of gummed paper. The other diamond was put away in a cabinet and kept far away from any radium compound. The two diamonds were thus left for a little more than six months. At the end of this time they were examined. No appreciable difference could be detected in the color of the two diamonds—the one that had been close to the tube of radium bromide not being darker than the one which had been away from radium the whole time.

COLORATION OF DIAMOND BY α-RAY.

9. The diamond was now enclosed for seventy-eight days in a tube containing radium bromide; at the end of the time it had acquired a bluish green color. It was then heated for ten days in a mixture of fuming nitric acid and potassium chlorate so as to dissolve off any outer skin of graphite which might have contributed to the color (3, 12, 32). The treatment brightened its appearance but did not alter the color. The diamond was next put on a sensitive photographic film and kept there for twenty-four hours. On developing, a strong impression was seen.

β- AND γ-RAYS PRODUCE PHOSPHORESCENCE.

10. This experiment shows that the alteration of the color is not due to the phosphorescent state of excitement to which the diamond had been constantly subjected during eight weeks. The coloring action is cut off by a thin screen of quartz, whereas the phosphorescing action is kept up by rays which pass through quartz. It is therefore evident that the coloration is due to the α-rays, or atoms of helium, shot from the radium compound (26, 29, 33). The phosphorescence is produced by the β- or γ-rays (19, 26, 43), which readily pass through glass and quartz.

PERSISTENCE OF ACQUIRED RADIO-ACTIVITY.

11. The acquired radio-activity of diamonds persists for a longer time than I have been enabled to measure, and resist the most violent treatment I have applied to them.

A large brilliant cut diamond of pure water assumed a fine green color after having been kept for sixteen months (from May, 1904, to September, 1905) in a bottle and covered with powdered radium bromide. At the end of that time it was highly radio-active. This diamond has been carried about in my pocket, off and on, since 1905, and has been tested on a sensitive photographic film at intervals of a year or more. No appreciable difference in its radio-activity can be detected from that which it possessed when first removed from the radium bromide in September, 1905. Examined at the present time, nine years after its removal from the bottle of radium bromide, it is luminous in the dark, it rapidly discharges a sensitive electroscope when held near it, and produces scintillations on a zinc sulphide screen as if it were a radium compound.

12. A diamond of good water was selected from a stock of inactive stones, and put in a tube of radium bromide for seventy-eight days. At the end of that time it had assumed a greenish color, and was highly radio-active. It was then heated to 50° C. in a mixture of fuming nitric acid and powdered potassium chlorate for ten days, the acid mixture being daily renewed (3, 9, 32). The only effect of this acid treatment was to remove a slight dull darkening on the surface, and to render the green tint more brilliant.

After well washing and drying it was put on a sensitive film for five hours. On developing it was seen that the stone had made a good impression on the film.

13. The stone was then sent to a diamond cutter to be cut into a brilliant. On receiving it back it was quite white and free from trace of color. The stone was then placed on a sensitive film and kept in darkness for twenty-two hours. On developing no impression was apparent, although, before cutting, the active diamond had impressed a film in five hours (12, 16).

EFFECT OF HEAT ON INDUCED RADIO-ACTIVITY.

14. A New South Wales diamond which had always been kept away from radium salts, was tested in the electroscope (2) and found to give a fall in two seconds, the natural leak being 180 seconds. The stone was then put in a silica crucible and heated in an electric tray furnace until visibly red. No change was observed. After 5 minutes—at, say, 700° C.—it was allowed to cool. The time of discharge in the electroscope was found to be six seconds.

15. The diamond was then packed in a silica crucible with graphite and heated with a Meker burner to 700° C. several times, cooling and testing the diamond each time when cold.

Heated to 700° C. for 10 mins., and cooled, time of fall = 6 secs.

Heated to 700° C. for 15 mins., and cooled, time of fall = 10 secs.

Heated to 700° C. for 20 mins., and cooled, time of fall = 10 secs.

Heated to 700° C. for 20 mins., and cooled, time of fall = 30 secs.

It was now left for the night, and measurements resumed next day.

Heated to 700° C. for 60 mins., time of fall = 9 secs.

Heated in new graphite for 30 mins., time of fall = 7 secs.

New graphite again used.

Tested again after 48 hours, time of fall = 4 secs.

Heated to 700° C. for 30 mins., and allowed to cool for 2 hours, time of fall = 2 secs.

The diamond after the last measurement (2 secs.) was laid on a sensitive film and kept in the dark for twenty-one days; on development it gave a good image.

This experiment shows a temporary loss of activity by the heat treatment followed in a short time by complete recovery.

16. A Kimberley diamond, rather flat, octahedral

*From *Philos. Trans., Royal Society* (London) and *Chem. News.*

shaped, was kept in a bottle of dry radium bromide for some weeks until it was quite green. By means of a steel wheel fed with diamond dust part of one face was cut away, and the surface of an adjoining face was just removed, the adjoining corner thus being freshly exposed diamond crystal. It was put on a sensitive film in such a position that it could be subsequently examined and compared with the developed image, so that the active portions of the surfaces, natural and ground off, could be seen. It was allowed to act for five days, when the film was developed. The result indicated very decidedly that where the surface of the diamond had been removed it was no longer radio-active (13).

EXPERIMENTS WITH A VERY ACTIVE DIAMOND CRYSTAL.

17. A fine crystal of diamond from Kimberley which had been kept in a bottle of radium bromide for some months was tested on a sensitive film and in the electroscope. It was found to be highly active, and was set aside for further experiments. It was luminous in the dark, quickly discharged the electroscope, and caused an inactive diamond held near it to phosphoresce. It was put on the surface of a screen coated with small crystals of barium platinocyanide, and caused scintillations the same as on a blende screen, but feebler (11, 26, 27, 30, 33).

18. A blende screen was made by coating a glass slip with very sensitive zinc sulphide. This was laid on the diamond, the ZnS side next the diamond; the scintillations were easily seen through it in all their characteristic appearance, with concentration at the edges and corners. A piece of aluminum sheet, 0.06 mm. thick, was moved about between the screen and crystal of diamond, and there was no doubt whatever that the aluminum stopped all the scintillations. It was absolutely dark where the aluminum covered the crystal.

19. The diamond (17) was then held in contact with the card back of a platinocyanide of barium screen. The luminous patch due to β- or γ-rays, or to both, was quite evident, moving about as the diamond was moved. The sheet of aluminum foil used in the former experiment (0.06 mm. thick) was put between the crystal and the back of the screen, and there was little, if any, diminution in the luminosity. It is therefore quite certain that the radio-active diamond gives off other rays besides α-rays, and that the rays can penetrate aluminum 0.06 mm. thick and the card back of the screen.

20. The diamond (17) was put into various fluorescent solutions (uranine in water, Silberrard's *p*-nitrosodimethyl-anilinenaphthaline compound, and quinine sulphate). It did not occasion the slightest fluorescence, although its own faint luminosity could be seen in the liquid.

21. The active diamond (17) was cemented to a plate of glass, and six small pillars of lead cemented round it the same height as the stone. The whole was inverted on a sensitive film, and kept in the dark for 2.25 hours. Another experiment was then tried with the same aparatus, only altering the position of the crystal so that the lead pillars were opposite the angles of the crystal. The exposure in this case was 6.5 hours. The pictures on development showed a strong radiation extending some distance round the diamond (six or eight diameters) and the lead pillars showed strong shadows.

22. The same experiment was repeated three times with the interposition of one, two, and three thicknesses of aluminum foil 0.01 mm. thick, each was exposed the same time (two hours), and all were developed together. Each showed strong action near the diamond. One thickness allowed the shadow of the lead pillars to be easily seen. Two thicknesses showed the shadow with difficulty, and three thicknesses only showed the shape of the diamond itself.

23. The crystal (17) was removed from its circle of lead pillars (21). A small cell of brass tube 0.5 inch in diameter had six slots cut in it with a file. The diamond was mounted in such a position that the three corners of the triangular surface that touched the film should come opposite three of the slots. These experiments show that the diamond is giving β-rays copiously.

γ-RAYS FROM THE RADIO ACTIVE DIAMOND.

24. The diamond (17) crystal was fixed with its sharpest point upwards in a small thick cell of brass. Exactly over the point was a small hole 0.5 mm. in diameter and 5mm. long. On the top was a piece of sensitive film enclosed in black paper. The whole was kept in the dark for three hours, when a fair image of the hole was obtained on development. The apparatus, with another sheet of sensitive film in it, was fixed between the pointed poles of a powerful electromagnet, and a current of 30 amperes was passed through for three hours. The current was then shut off, and the film shifted sideways for half an inch, and the action of the diamond without the magnetism was allowed to go on for another three hours. It was then developed, and both spots appeared about the same intensity.

25. The diamond crystal (17) in its brass box had a thin plate of clear mica put over the hole, and a sheet of lead over that. All was wrapped in sheet lead, and so kept for about six months. There was an extremely faint but hardly appreciable darkening of the mica at the position of the hole.

26. After the above experiment the diamond was kept in its brass box for two years, and then laid on a sensitive film and kept for three hours. On developing a spot of action was seen, showing that the diamond was still radio-active. It was removed from its brass cell and examined in the dark on a blende screen. It gave plenty of scintillations easily visible without a lens. Experiments showed that it still gave out, along with α-rays, also β-rays and γ-rays (10, 19, 42, 43).

27. A small light-tight box was fitted as a camera. The arrangements were such that the image on the sensitive film was 1.5 times the size of the object. A photograph of the radio-active diamond (17) was taken by the light of its scintillations on the blende screen (17, 26, 30, 33), giving forty-eight hours' exposure. The three bunches of luminosity come from the corners of the crystal that are in contact with the screen. The photographic impression is certainly discontinuous, appearing granular—corresponding to the granular character of the screen. It appears that the different grains shine and continue to shine by their own residual phosphorescent light under the impact of the α-particles. In a further experiment the diamond was illuminated by the arc lamp, and a photograph was made of the diamond crystal *in situ* as well as of the screen. This gave a good image of the stone, and also of the granular surface of the screen.

28. It is certain that, in addition to α-rays, the diamond (17) gives off a considerable amount of other rays (10, 19, 26, 42, 43). This is shown by the early experiments, where photographic images with the diamond were obtained through one, two, three, and four sheets of aluminum foil—each 0.01 mm. thick.

29. The crystal of active diamond (17), with which most of these experiments have been made, was examined crystallographically by Dr. Tutton, who reported to me that the crystal is an apparent octahedron—but composed of two supplementary tetrahedra showing on three of the edges the usual grooves where the interpenetration of the tetrahedra is not complete.

30. Experiments show that exposure of a zinc-sulphide screen to the impact of electrons from the negative pole in a vacuum tube does not cause scintillations. It appears that only α-rays (positive atoms) produce this effect (11, 17, 62, 27, 33); it was therefore interesting to see if scintillations could be produced by bombarding a sulphide screen with a stream of positive atoms produced in a "Thompson" tube. An apparatus was fitted up having a zinc-sulphide screen to receive the positive discharge—but no effect of scintillation could be observed.

(*To be continued*)

Lignum-Vitae, the Vital Wood

(*Continued from page 5*)

which grows in Venezuela and Colombia and bears the same local names. The logs are from 3 to 5 feet long and 4 to 14 inches in diameter. The bark of the various shipments examined by the writer is of an entirely different nature and appearance from that of the genuine wood, being rough and scaly instead of smooth with rather large flakes. It is believed that a large amount of genuine lignum-vitæ exists in Haiti, but owing to its large size the natives find it too difficult to get out, since the transportation facilities in the interior are extremely poor.

Nicaraguan lignum-vitæ has been on the market for many years but there is considerable objection to its qualities on the part of certain users, especially in France, England, Holland and Denmark, who assert that it has too great a tendency to check and split. On the other hand it has been used with success in Japan, China, Germany and to a greater or less extent in the United States. The shipyards on the Pacific coast use it exclusively. It seems likely that the objectionable features could be overcome through improved methods of handling and manufacture. The largest log of available record was 36 inches in diameter, 9 feet in length and weighed 4,260 pounds. Usually the logs are from 4 to 8 feet long and from 9 to 24 inches through, with a good percentage over 12 inches. They are straight, smooth and cylindrical and free from defects except end checks which give a bad appearance but generally do not penetrate deeply.

The amount of lignum-vitæ coming out of Mexico is at present very small. The writer had occasion to inspect a carload of logs from the northwestern part of the country and found them of various lengths up to 6 feet and ranging in diameter from 8 to 11 inches. They were all more or less faulty, being crooked, gnarly and knotty, with wide sap and small hearts which were often affected with rot. The writer was unable to determine whether or not this shipment was typical of the region.

FUTURE SOURCES OF SUPPLY.

The West Indies will probably continue to supply the bulk of the high-grade lignum-vitæ for many years if prices remain at sufficiently high levels to warrant the increased expense attending the more and more difficult logging. Improvement of the transportation facilities and logging methods in certain regions will permit the getting out of material now too large to be handled in the primitive native manner over rough trails.

There is believed to be a large supply of accessible lignum-vitæ in Nicaragua but the prejudice against this material is retarding its exploitation. It is reported that the Government of Honduras is taking steps to introduce its wood into the market but it is likely to encounter the same opposition as in the case of the Nicaraguan wood. There is need for thorough investigation of the properties and behavior of these and other kinds of lignum-vitæ with a view to their standardization and to the devising of methods of treatment and manufacture which will overcome or minimize the difficulties in their utilization. It is of much greater importance now to make some of the so-called inferior grades acceptable than it is to search for substitutes among woods of entirely different structure and properties.

There is a very considerable quantity of true lignum-vitæ in the coastal region of Colombia and Venezuela. Very little of it is now on the market, partly because the trade fears the substitution of "vera" or "Maracaibo lignum-vitæ" for the genuine. In 1917 a shipment of a few tons was received by a New York dealer from the Port of Colombia. The logs were 5 or 6 feet long, 4 to 15 inches in diameter, straight and well-shaped and with all the sapwood trimmed off. It proved to be excellent wood, approximating Cuban quality, according to report.

The "Maracaibo lignum-vitæ" or vera (*Bulnesia arborea*) is much like the genuine lignum-vitæ (*Guaiacum* sp.) in being dense, cross-grained and resinous. It is not, however, considered suitable for bearings and certain other exacting purposes, the claim being that it does not wear well and that the grain is less interwoven than in the best of the genuine wood, consequently there is more liability to cup-shakes, radial cracks and similar defects. One New York dealer told the writer that 75 per cent. of the vera logs he had seen showed bad ring-shakes. The lower resistance to wear may be due to the very large number of crystals present in the wood of this genus since they would tend to act as very fine but sharp grit in bearings. The writer was unable to determine the extent to which these objections are justifiable. The fact remains that the wood is less used now than it was a few years ago and is in little demand at a price from one-third to one-half that of Cuban.

There is a possibility of "Paraguay lignum-vitæ" or "palo santo," as it is known locally, entering the market. It grows in mixture with quebracho, which is in such demand for the tannin extract, and timberland owners are looking for an outlet for their "lignum-vitæ." This is not the genuine wood but another species of *Bulnesia*. It has been an article of export for many years but only in small quantities for the manufacture of an essential oil, "oil of guaiac wood," used in the manufacture of certain perfumery.

SUBSTITUTES FOR LIGNUM-VITAE.

No acceptable substitute has ever been found for lignum-vitæ for stern bearings and certain other exacting uses. The "mancano" of the Philippines was urged for this purpose but has not found favor. The "varnish-tree" of India has been suggested by various writers but is apparently unsuited. A New York dealer informs the writer that he has been offered 100 tons of "African lignum-vitæ," but the nature of this wood and the species of tree producing it are unknown. Genuine lignum-vitæ does not grow naturally anywhere in the world except in tropical America, though various woods, especially in Australia, go by that name.

During the war when the demands of the ship-build-

ing industry were especially heavy and genuine lignum-vitæ stocks were short on account of limited shipping facilities, an inferior substitute, known as "Panama lignum-vitæ" or "yellow guayacan" was used by the Emergency Fleet Corporation. This came about largely through confusion of names. The Panama wood in question is locally known as "guayacan," a name also applied to the genuine wood, although the two are of entirely different families of trees and are wholly unlike in structure and properties. Yellow guayacan (*Tabebuia* sp.) seems to be lacking in the essential properties of genuine lignum-vitæ and is probably no better suited for stern bearings than our native beech which was formerly used in a small way.

Regarding the use of yellow guayacan, the Bureau of Construction and Repair of the U. S. Navy Department advises the writer in a letter dated March 29, 1919, that it "made one purchase of *Tabebuia* with the expectation that this material would be suitable for the same uses for which the genuine lignum-vitæ is required. Tests have proven that this material has sufficient strength and hardness but is lacking in oil content which prohibits its use for stern bearings which require wood of self-lubricating properties."

The writer was recently informed by a person familiar with the timbers of Central America that at least 40 different kinds of woods are locally called "guayacan." The experience with the Panama wood shows the danger lurking in that name and emphasizes the need for discrimination on the part of users and buyers of lignum-vitæ if they would avoid being imposed on, whether intentionally or otherwise.

Experimental Wireless

(*Continued from page 13*)

On airplanes, dirigibles, and other aircraft in general, the antenna system consists of a trailing wire in most cases. While the aircraft is in flight, a wire several hundred feet in length is paid out from a reel. A stream-lined weight is fastened to the free end of the wire, so as to keep it trailing behind the aircraft. When the aircraft is about to land, the wire is taken up on the reel. In some airplanes the aerial consists of wires stretched between posts on the top wings, or between other members. In the case of at least one dirigible, namely, the C-5 of the United States Navy, which was blown to sea after a successful flight to Newfoundland, the aerial wires were placed inside the gasbag.

A live tree makes an excellent antenna for receiving. In fact, during a recent U. S. Signal Corps demonstration at Washington, D. C., a live tree was employed in receiving messages from powerful stations in Europe. Of course, most of these improvised aerials are only suitable for receiving purposes, because in transmitting it is imperative to have a good aerial in order to impart the waves to the ether in the most efficient manner. However, it must not be inferred from all that has been written, so far, that one aerial is required for the transmitter and another for the receiver. If an aerial is of the proper design and size, it may be employed for receiving and transmitting; and for this purpose a switch is employed which permits of connecting either set with the aerial at will.

As for the so-called ground or earth connection, this is merely a matter of a good electrical connection with the ground, or a capacity effect. On shipboard the problem is merely one of securing a connection with the metal hull, or if the ship is of the wooden design, having a plate in the water. In the city, the ground is merely a connection with a water or gas pipe, preferably the former. In the country the ground may be a special one, prepared with little trouble. In localities where it is next to impossible to make a good contact with the earth, such as in sandy or rocky regions, one resorts to the capacity ground or so-called counterpoise, which is nothing more than an arrangement of wires laid on the ground or supported a short distance above the ground, arranged very much after the fashion of the antenna but much lower, of course. Still another form of counterpoise is a piece of wire netting, spread on the surface. In the case of aircraft, the ground is also of the capacity of counterpoise type. The wires of the rigging are used to form a capacity ground.

Hence it becomes obvious that the term "ground" is a misleading one, particularly in cases where there is no ground connection at all. However, it is the accepted term and must therefore be abided by.

Coming to the receiving side of wireless communication, we find the situation just the reverse of the transmitter. The currents induced in the aerial by the intercepted radio waves flow down through the aerial circuit, and are transferred to the receiving circuit, where they operate certain instruments which in turn give the operator some indication of their passage.

Practically speaking, a receiver does not take away from the power of the transmitter; that is to say, whether a thousand or ten receiving stations are receiving a message at one time, the effect on the transmitter is the same. Indeed, it is never known whether one's transmitted signals are being picked up or not, unless one receives an acknowledgment. The transmitted waves spread out in all directions to be picked up or not, growing weaker and weaker the farther they go away from the transmitter. A receiver which is sufficiently sensitive may be made to intercept the waves within the range of the transmitter. It follows that the farther a receiving set is from a given transmitter, the more delicate it must be. That fact explains why almost any kind of aerial—even a common umbrella or a short length of stove-pipe—and a crude receiving set may be used for receiving nearby signals.

THE IMPORTANT MATTER OF TUNING.

Now all wireless waves are not alike; they have different wavelength values as already indicated. Wavelengths vary from 40 to 18,000 meters, the longer values being used in long-distance, high-power stations, while the shorter wavelengths are employed by the Government, ship stations and amateurs.

This matter of wavelengths is a most important one in radio communication. All transmitters emit signals of varying wavelengths, and all receiving stations may be adjusted to receive signals of any wavelength, and hence signals from any transmitter. Thus if transmitter A is emitting signals on a wavelength of 300 meters, and transmitter B is emitting signals of 600 meters, a receiving set can be adjusted for 300 meters to receive from A, or 600 meters to receive from B. It is this matter of transmitting signals of a given wavelength and picking them up at the receiving station which is known as tuning. And it is this tuning which permits several transmitters and receivers to operate in a given locality at one time, without unduly interfering with one another.

Indeed, the most practical example of the value of tuning is offered in the regulations applying to amateur wireless in the United States, which specify that amateur transmitters must be tuned to wavelengths below 200 meters. In this manner the commercial and Government transmitters, operating on longer wavelengths, can communicate with their respective receiving stations without interference of the shorter wavelength transmitters.

In practice, tuning is not as perfect as one would hope for. That is to say, even despite a wide difference in tune, one transmitter may seriously interfere with another. This is usually the case when one transmitter is quite close to a receiving station, while the desired transmitter is some distance away. Even though the receiving station is tuned for the distant transmitter, the signals of the nearby transmitter force themselves on the receiver. This result is known as forced oscillations.

Tuning is a matter of varying the oscillating or radio frequency of wavelength. Most transmitters, unless they are of the "fixed" variety, can be generally tuned to any desired wavelength over a considerable range, by varying the capacity and inductance in the oscillating and the aerial circuit, while the receiving set can also be varied by varying the capacity and inductance in the aerial and associated circuits.

The currents induced in the receiving aerial by the passage of signal waves are transferred to the receiving circuit proper. Between the two circuits there may be a close or loose coupling, according to requirements. These currents, being of the high-frequency alternating current category, cannot be detected by ordinary electrical apparatus. A telephone receiver, for instance, while sensitive in the extreme and responsive to weak electrical currents, will not respond to these high-frequency currents. The reasons why a telephone receiver cannot be connected to the high-frequency circuit are: In the first place, the little magnet coils contained in the receiver exert a choking effect upon the currents of such high frequency, which effectually blocks their passage. Low frequency and of audible nature, intermittent direct currents and continuous direct currents will readily pass, producing a sound each time there is any change in their value. Hence it becomes necessary to convert the high-frequency alternating currents into some form of current that can operate the telephone receiver.

Various methods are available for converting and detecting high-frequency currents in a receiving circuit, among these being ingenious rectifying devices, sensitive modifiers which modify a telephone circuit in accordance with the varying strength of the antenna currents, electric lamps of special construction known as vacuum tubes, and so on. The device that converts the antenna currents so that they may be detected with a telephone receiver, is known as the detector.

The purpose and action of most types of detectors are to act as a valve, allowing the current to pass through in one direction only, or offering what is known as a uni-lateral conduction to the current. The action is clearly shown in the last of the remaining sketches, depicting first the high-frequency current, and then the same current after passing through the detector.

The average receiving set comprises tuning instruments, for varying the antenna and receiving circuit so as to bring the receiving apparatus in tune with the desired signals, a detector, a pair of telephone receivers, and the miscellaneous equipment necessary to round out the installation. Sitting before his tuning instrument, the operator can, by the mere turn of a knob or two, search through the entire range of wavelengths, picking up the various signals then passing through space as he gets in tune with them. Indeed, that is one of the greatest fascinations of radio—this matter of eavesdropping, so to speak, on all transmitting stations at will, while being instantly able to concentrate on any one by sharp tuning.

So much for a broad introduction to the subject of radio communication. In subsequent chapters the actual installation and operation of radio equipment are taken up in proper turn.

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